



## Thalasar Ventures Python Documentation Project

Like most open source projects this one started with a very simple problem. A friend of mine wanted a quick PDF of all the documentation for Python in a simple pdf.

Rather than do it himself, he asked if I could spend some time putting a little bit more order to documents.

The documentation is of course freely available under an open source license but consists of 26 separate PDFs without any structure or order. I decided to put it together for him quickly with additional bookmarks that made browsing the document a bit easier.

It naturally occurred to me that other people would like the convenience of a single PDF that contains all the documentation for Python. So here it is. I am publishing this as both a PDF and Kindle formatted document at Amazon. If you purchase at Amazon, 50% of the net proceeds will go to the Python Foundation. I will keep a weekly total of proceeds donated to the Python Foundation at my blog at Thalasar.com

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I have applied the ink sketch filter to create the effect.

Please enjoy the documentation (as much as it can be enjoyed) and I would love to get any feedback you might have. [brian@thalasar.com](mailto:brian@thalasar.com) is where I can be best reached.

Brian Despain

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# What's New in Python

*Release 2.7.3*

**A. M. Kuchling**

September 24, 2012

**Python Software Foundation**

Email: docs@python.org

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**Author** A.M. Kuchling (amk at amk.ca)

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This article explains the new features in Python 2.7. Python 2.7 was released on July 3, 2010.

Numeric handling has been improved in many ways, for both floating-point numbers and for the `Decimal` class. There are some useful additions to the standard library, such as a greatly enhanced `unittest` module, the `argparse` module for parsing command-line options, convenient `OrderedDict` and `Counter` classes in the `collections` module, and many other improvements.

Python 2.7 is planned to be the last of the 2.x releases, so we worked on making it a good release for the long term. To help with porting to Python 3, several new features from the Python 3.x series have been included in 2.7.

This article doesn't attempt to provide a complete specification of the new features, but instead provides a convenient overview. For full details, you should refer to the documentation for Python 2.7 at <http://docs.python.org>. If you want to understand the rationale for the design and implementation, refer to the PEP for a particular new feature or the issue on <http://bugs.python.org> in which a change was discussed. Whenever possible, "What's New in Python" links to the bug/patch item for each change.

## 1 The Future for Python 2.x

Python 2.7 is intended to be the last major release in the 2.x series. The Python maintainers are planning to focus their future efforts on the Python 3.x series.

This means that 2.7 will remain in place for a long time, running production systems that have not been ported to Python 3.x. Two consequences of the long-term significance of 2.7 are:

- It's very likely the 2.7 release will have a longer period of maintenance compared to earlier 2.x versions. Python 2.7 will continue to be maintained while the transition to 3.x continues, and the developers are planning to support Python 2.7 with bug-fix releases beyond the typical two years.
- A policy decision was made to silence warnings only of interest to developers. `DeprecationWarning` and its descendants are now ignored unless otherwise requested, preventing users from seeing warnings triggered by an application. This change was also made in the branch that will become Python 3.2. (Discussed on `stdlib-sig` and carried out in [issue 7319](#).)

In previous releases, `DeprecationWarning` messages were enabled by default, providing Python developers with a clear indication of where their code may break in a future major version of Python.

However, there are increasingly many users of Python-based applications who are not directly involved in the development of those applications. `DeprecationWarning` messages are irrelevant to such users, making them worry about an application that's actually working correctly and burdening application developers with responding to these concerns.

You can re-enable display of `DeprecationWarning` messages by running Python with the `-Wdefault` (short form: `-Wd`) switch, or by setting the `PYTHONWARNINGS` environment variable to "default" (or "d") before running Python. Python code can also re-enable them by calling `warnings.simplefilter('default')`.

## 2 Python 3.1 Features

Much as Python 2.6 incorporated features from Python 3.0, version 2.7 incorporates some of the new features in Python 3.1. The 2.x series continues to provide tools for migrating to the 3.x series.

A partial list of 3.1 features that were backported to 2.7:

- The syntax for set literals (`{1, 2, 3}` is a mutable set).
- Dictionary and set comprehensions (`{i: i*2 for i in range(3)}`).
- Multiple context managers in a single `with` statement.
- A new version of the `io` library, rewritten in C for performance.
- The ordered-dictionary type described in *PEP 372: Adding an Ordered Dictionary to collections*.
- The new `_, _` format specifier described in *PEP 378: Format Specifier for Thousands Separator*.
- The `memoryview` object.
- A small subset of the `importlib` module, [described below](#).
- The `repr()` of a float `x` is shorter in many cases: it's now based on the shortest decimal string that's guaranteed to round back to `x`. As in previous versions of Python, it's guaranteed that `float(repr(x))` recovers `x`.
- Float-to-string and string-to-float conversions are correctly rounded. The `round()` function is also now correctly rounded.
- The `PyCapsule` type, used to provide a C API for extension modules.
- The `PyLong_AsLongAndOverflow()` C API function.

Other new Python3-mode warnings include:

- `operator.isCallable()` and `operator.sequenceIncludes()`, which are not supported in 3.x, now trigger warnings.
- The `-3` switch now automatically enables the `-Qwarn` switch that causes warnings about using classic division with integers and long integers.

## 3 PEP 372: Adding an Ordered Dictionary to collections

Regular Python dictionaries iterate over key/value pairs in arbitrary order. Over the years, a number of authors have written alternative implementations that remember the order that the keys were originally inserted. Based on the experiences from those implementations, 2.7 introduces a new `OrderedDict` class in the `collections` module.

The `OrderedDict` API provides the same interface as regular dictionaries but iterates over keys and values in a guaranteed order depending on when a key was first inserted:

```
>>> from collections import OrderedDict
>>> d = OrderedDict([('first', 1),
...                 ('second', 2),
...                 ('third', 3)])
>>> d.items()
[('first', 1), ('second', 2), ('third', 3)]
```

If a new entry overwrites an existing entry, the original insertion position is left unchanged:

```
>>> d['second'] = 4
>>> d.items()
[('first', 1), ('second', 4), ('third', 3)]
```

Deleting an entry and reinserting it will move it to the end:

```
>>> del d['second']
>>> d['second'] = 5
>>> d.items()
[('first', 1), ('third', 3), ('second', 5)]
```

The `popitem()` method has an optional `last` argument that defaults to `True`. If `last` is `True`, the most recently added key is returned and removed; if it's `False`, the oldest key is selected:

```
>>> od = OrderedDict([(x, 0) for x in range(20)])
>>> od.popitem()
(19, 0)
>>> od.popitem()
(18, 0)
>>> od.popitem(last=False)
(0, 0)
>>> od.popitem(last=False)
(1, 0)
```

Comparing two ordered dictionaries checks both the keys and values, and requires that the insertion order was the same:

```
>>> od1 = OrderedDict([('first', 1),
...                   ('second', 2),
...                   ('third', 3)])
>>> od2 = OrderedDict([('third', 3),
...                   ('first', 1),
...                   ('second', 2)])
>>> od1 == od2
False
>>> # Move 'third' key to the end
>>> del od2['third']; od2['third'] = 3
>>> od1 == od2
True
```

Comparing an `OrderedDict` with a regular dictionary ignores the insertion order and just compares the keys and values.

How does the `OrderedDict` work? It maintains a doubly-linked list of keys, appending new keys to the list as they're inserted. A secondary dictionary maps keys to their corresponding list node, so deletion doesn't have to traverse the entire linked list and therefore remains  $O(1)$ .

The standard library now supports use of ordered dictionaries in several modules.

- The `ConfigParser` module uses them by default, meaning that configuration files can now be read, modified, and then written back in their original order.
- The `_asdict()` method for `collections.namedtuple()` now returns an ordered dictionary with the values appearing in the same order as the underlying tuple indices.
- The `json` module's `JSONDecoder` class constructor was extended with an `object_pairs_hook` parameter to allow `OrderedDict` instances to be built by the decoder. Support was also added for third-party tools like [PyYAML](#).

**See Also:**

**PEP 372 - Adding an ordered dictionary to collections** PEP written by Armin Ronacher and Raymond Hettinger; implemented by Raymond Hettinger.

## 4 PEP 378: Format Specifier for Thousands Separator

To make program output more readable, it can be useful to add separators to large numbers, rendering them as 18,446,744,073,709,551,616 instead of 18446744073709551616.

The fully general solution for doing this is the `locale` module, which can use different separators ("," in North America, "." in Europe) and different grouping sizes, but `locale` is complicated to use and unsuitable for multi-threaded applications where different threads are producing output for different locales.

Therefore, a simple comma-grouping mechanism has been added to the mini-language used by the `str.format()` method. When formatting a floating-point number, simply include a comma between the width and the precision:

```
>>> '{:20,.2f}'.format(18446744073709551616.0)
'18,446,744,073,709,551,616.00'
```

When formatting an integer, include the comma after the width:

```
>>> '{:20,d}'.format(18446744073709551616)
'18,446,744,073,709,551,616'
```

This mechanism is not adaptable at all; commas are always used as the separator and the grouping is always into three-digit groups. The comma-formatting mechanism isn't as general as the `locale` module, but it's easier to use.

**See Also:**

**PEP 378 - Format Specifier for Thousands Separator** PEP written by Raymond Hettinger; implemented by Eric Smith.

## 5 PEP 389: The `argparse` Module for Parsing Command Lines

The `argparse` module for parsing command-line arguments was added as a more powerful replacement for the `optparse` module.

This means Python now supports three different modules for parsing command-line arguments: `getopt`, `optparse`, and `argparse`. The `getopt` module closely resembles the C library's `getopt()` function, so it remains useful if you're writing a Python prototype that will eventually be rewritten in C. `optparse` becomes redundant, but there are no plans to remove it because there are many scripts still using it, and there's no automated way to update these scripts. (Making the `argparse` API consistent with `optparse`'s interface was discussed but rejected as too messy and difficult.)

In short, if you're writing a new script and don't need to worry about compatibility with earlier versions of Python, use `argparse` instead of `optparse`.

Here's an example:

```
import argparse
```

```
parser = argparse.ArgumentParser(description='Command-line example.')
```

```
# Add optional switches
```

```
parser.add_argument('-v', action='store_true', dest='is_verbose',
                    help='produce verbose output')
```

```
parser.add_argument('-o', action='store', dest='output',
                    metavar='FILE',
                    help='direct output to FILE instead of stdout')
```

```
parser.add_argument('-C', action='store', type=int, dest='context',
                    metavar='NUM', default=0,
                    help='display NUM lines of added context')
```

```
# Allow any number of additional arguments.
parser.add_argument(nargs='*', action='store', dest='inputs',
                    help='input filenames (default is stdin)')
```

```
args = parser.parse_args()
print args.__dict__
```

Unless you override it, `-h` and `--help` switches are automatically added, and produce neatly formatted output:

```
-> ./python.exe argparse-example.py --help
usage: argparse-example.py [-h] [-v] [-o FILE] [-C NUM] [inputs [inputs ...]]
```

Command-line example.

```
positional arguments:
  inputs          input filenames (default is stdin)
```

```
optional arguments:
  -h, --help  show this help message and exit
  -v          produce verbose output
  -o FILE     direct output to FILE instead of stdout
  -C NUM     display NUM lines of added context
```

As with `optparse`, the command-line switches and arguments are returned as an object with attributes named by the *dest* parameters:

```
-> ./python.exe argparse-example.py -v
{'output': None,
 'is_verbose': True,
 'context': 0,
 'inputs': []}

-> ./python.exe argparse-example.py -v -o /tmp/output -C 4 file1 file2
{'output': '/tmp/output',
 'is_verbose': True,
 'context': 4,
 'inputs': ['file1', 'file2']}
```

`argparse` has much fancier validation than `optparse`; you can specify an exact number of arguments as an integer, 0 or more arguments by passing `'*'`, 1 or more by passing `'+'`, or an optional argument with `'?'`. A top-level parser can contain sub-parsers to define subcommands that have different sets of switches, as in `svn commit`, `svn checkout`, etc. You can specify an argument's type as `FileType`, which will automatically open files for you and understands that `'-'` means standard input or output.

#### See Also:

**argparse documentation** The documentation page of the `argparse` module.

**argparse-from-optparse** Part of the Python documentation, describing how to convert code that uses `optparse`.

**PEP 389 - argparse - New Command Line Parsing Module** PEP written and implemented by Steven Bethard.

## 6 PEP 391: Dictionary-Based Configuration For Logging

The logging module is very flexible; applications can define a tree of logging subsystems, and each logger in this tree can filter out certain messages, format them differently, and direct messages to a varying number of handlers.

All this flexibility can require a lot of configuration. You can write Python statements to create objects and set their properties, but a complex set-up requires verbose but boring code. `logging` also supports a `fileConfig()` function that parses a file, but the file format doesn't support configuring filters, and it's messier to generate programmatically.

Python 2.7 adds a `dictConfig()` function that uses a dictionary to configure logging. There are many ways to produce a dictionary from different sources: construct one with code; parse a file containing JSON; or use a YAML parsing library if one is installed. For more information see *logging-config-api*.

The following example configures two loggers, the root logger and a logger named "network". Messages sent to the root logger will be sent to the system log using the syslog protocol, and messages to the "network" logger will be written to a `network.log` file that will be rotated once the log reaches 1MB.

```
import logging
import logging.config

configdict = {
    'version': 1,          # Configuration schema in use; must be 1 for now
    'formatters': {
        'standard': {
            'format': ('%(asctime)s %(name)-15s '
                       '%(levelname)-8s %(message)s')
        },
    },
    'handlers': {'netlog': {'backupCount': 10,
                            'class': 'logging.handlers.RotatingFileHandler',
                            'filename': '/logs/network.log',
                            'formatter': 'standard',
                            'level': 'INFO',
                            'maxBytes': 1000000},
                 'syslog': {'class': 'logging.handlers.SysLogHandler',
                             'formatter': 'standard',
                             'level': 'ERROR'}},
    # Specify all the subordinate loggers
    'loggers': {
        'network': {
            'handlers': ['netlog']
        },
    },
    # Specify properties of the root logger
    'root': {
        'handlers': ['syslog']
    },
}

# Set up configuration
logging.config.dictConfig(configdict)

# As an example, log two error messages
logger = logging.getLogger('/')
logger.error('Database not found')

netlogger = logging.getLogger('network')
netlogger.error('Connection failed')
```

Three smaller enhancements to the logging module, all implemented by Vinay Sajip, are:

- The `SysLogHandler` class now supports syslogging over TCP. The constructor has a *socktype* parameter giving the type of socket to use, either `socket.SOCK_DGRAM` for UDP or `socket.SOCK_STREAM` for TCP. The default protocol remains UDP.
- Logger instances gained a `getChild()` method that retrieves a descendant logger using a relative path. For example, once you retrieve a logger by doing `log = getLogger('app')`, calling `log.getChild('network.listen')` is equivalent to `getLogger('app.network.listen')`.
- The `LoggerAdapter` class gained a `isEnabledFor()` method that takes a *level* and returns whether the underlying logger would process a message of that level of importance.

**See Also:**

**PEP 391 - Dictionary-Based Configuration For Logging** PEP written and implemented by Vinay Sajip.

## 7 PEP 3106: Dictionary Views

The dictionary methods `keys()`, `values()`, and `items()` are different in Python 3.x. They return an object called a *view* instead of a fully materialized list.

It's not possible to change the return values of `keys()`, `values()`, and `items()` in Python 2.7 because too much code would break. Instead the 3.x versions were added under the new names `viewkeys()`, `viewvalues()`, and `viewitems()`.

```
>>> d = dict((i*10, chr(65+i)) for i in range(26))
>>> d
{0: 'A', 130: 'N', 10: 'B', 140: 'O', 20: ..., 250: 'Z'}
>>> d.viewkeys()
dict_keys([0, 130, 10, 140, 20, 150, 30, ..., 250])
```

Views can be iterated over, but the key and item views also behave like sets. The `&` operator performs intersection, and `|` performs a union:

```
>>> d1 = dict((i*10, chr(65+i)) for i in range(26))
>>> d2 = dict((i**.5, i) for i in range(1000))
>>> d1.viewkeys() & d2.viewkeys()
set([0.0, 10.0, 20.0, 30.0])
>>> d1.viewkeys() | range(0, 30)
set([0, 1, 130, 3, 4, 5, 6, ..., 120, 250])
```

The view keeps track of the dictionary and its contents change as the dictionary is modified:

```
>>> vk = d.viewkeys()
>>> vk
dict_keys([0, 130, 10, ..., 250])
>>> d[260] = '&'
>>> vk
dict_keys([0, 130, 260, 10, ..., 250])
```

However, note that you can't add or remove keys while you're iterating over the view:

```
>>> for k in vk:
...     d[k*2] = k
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
RuntimeError: dictionary changed size during iteration
```

You can use the view methods in Python 2.x code, and the 2to3 converter will change them to the standard `keys()`, `values()`, and `items()` methods.

**See Also:**

**PEP 3106 - Revamping `dict.keys()`, `.values()` and `.items()`** PEP written by Guido van Rossum. Backported to 2.7 by Alexandre Vassalotti; [issue 1967](#).

## 8 PEP 3137: The `memoryview` Object

The `memoryview` object provides a view of another object's memory content that matches the `bytes` type's interface.

```
>>> import string
>>> m = memoryview(string.letters)
>>> m
<memory at 0x37f850>
>>> len(m)           # Returns length of underlying object
52
>>> m[0], m[25], m[26] # Indexing returns one byte
('a', 'z', 'A')
>>> m2 = m[0:26]      # Slicing returns another memoryview
>>> m2
<memory at 0x37f080>
```

The content of the view can be converted to a string of bytes or a list of integers:

```
>>> m2.tobytes()
'abcdefghijklmnopqrstuvwxy'
>>> m2.tolist()
[97, 98, 99, 100, 101, 102, 103, ... 121, 122]
>>>
```

`memoryview` objects allow modifying the underlying object if it's a mutable object.

```
>>> m2[0] = 75
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot modify read-only memory
>>> b = bytearray(string.letters) # Creating a mutable object
>>> b
bytearray(b'abcdefghijklmnopqrstuvwxyABCDEFGHIJKLMNOPQRSTUVWXYZ')
>>> mb = memoryview(b)
>>> mb[0] = '*' # Assign to view, changing the bytearray.
>>> b[0:5]      # The bytearray has been changed.
bytearray(b'*bcde')
>>>
```

**See Also:**

**PEP 3137 - Immutable Bytes and Mutable Buffer** PEP written by Guido van Rossum. Implemented by Travis Oliphant, Antoine Pitrou and others. Backported to 2.7 by Antoine Pitrou; [issue 2396](#).

## 9 Other Language Changes

Some smaller changes made to the core Python language are:

- The syntax for set literals has been backported from Python 3.x. Curly brackets are used to surround the contents of the resulting mutable set; set literals are distinguished from dictionaries by not containing colons and values. `{}` continues to represent an empty dictionary; use `set()` for an empty set.

```
>>> {1, 2, 3, 4, 5}
set([1, 2, 3, 4, 5])
>>> set() # empty set
set([])
>>> {}    # empty dict
{}
```

Backported by Alexandre Vassalotti; [issue 2335](#).

- Dictionary and set comprehensions are another feature backported from 3.x, generalizing list/generator comprehensions to use the literal syntax for sets and dictionaries.

```
>>> {x: x*x for x in range(6)}
{0: 0, 1: 1, 2: 4, 3: 9, 4: 16, 5: 25}
>>> {'a'*x for x in range(6)}
set(['', 'a', 'aa', 'aaa', 'aaaa', 'aaaaa'])
```

Backported by Alexandre Vassalotti; [issue 2333](#).

- The `with` statement can now use multiple context managers in one statement. Context managers are processed from left to right and each one is treated as beginning a new `with` statement. This means that:

```
with A() as a, B() as b:
    ... suite of statements ...
```

is equivalent to:

```
with A() as a:
    with B() as b:
        ... suite of statements ...
```

The `contextlib.nested()` function provides a very similar function, so it's no longer necessary and has been deprecated.

(Proposed in <http://codereview.appspot.com/53094>; implemented by Georg Brandl.)

- Conversions between floating-point numbers and strings are now correctly rounded on most platforms. These conversions occur in many different places: `str()` on floats and complex numbers; the `float` and `complex` constructors; numeric formatting; serializing and deserializing floats and complex numbers using the `marshal`, `pickle` and `json` modules; parsing of float and imaginary literals in Python code; and Decimal-to-float conversion.

Related to this, the `repr()` of a floating-point number `x` now returns a result based on the shortest decimal string that's guaranteed to round back to `x` under correct rounding (with round-half-to-even rounding mode). Previously it gave a string based on rounding `x` to 17 decimal digits.

The rounding library responsible for this improvement works on Windows and on Unix platforms using the `gcc`, `icc`, or `suncc` compilers. There may be a small number of platforms where correct operation of this code cannot be guaranteed, so the code is not used on such systems. You can find out which code is being used by checking `sys.float_repr_style`, which will be `short` if the new code is in use and `legacy` if it isn't.

Implemented by Eric Smith and Mark Dickinson, using David Gay's `dtoa.c` library; [issue 7117](#).

- Conversions from long integers and regular integers to floating point now round differently, returning the floating-point number closest to the number. This doesn't matter for small integers that can be converted exactly, but for large numbers that will unavoidably lose precision, Python 2.7 now approximates more closely. For example, Python 2.6 computed the following:

```
>>> n = 295147905179352891391
>>> float(n)
2.9514790517935283e+20
>>> n - long(float(n))
65535L
```

Python 2.7's floating-point result is larger, but much closer to the true value:

```
>>> n = 295147905179352891391
>>> float(n)
2.9514790517935289e+20
>>> n - long(float(n))
-1L
```

(Implemented by Mark Dickinson; [issue 3166](#).)

Integer division is also more accurate in its rounding behaviours. (Also implemented by Mark Dickinson; [issue 1811](#).)

- Implicit coercion for complex numbers has been removed; the interpreter will no longer ever attempt to call a `__coerce__()` method on complex objects. (Removed by Meador Inge and Mark Dickinson; [issue 5211](#).)
- The `str.format()` method now supports automatic numbering of the replacement fields. This makes using `str.format()` more closely resemble using `%s` formatting:

```
>>> '{}: {}: {}'.format(2009, 04, 'Sunday')
'2009:4:Sunday'
>>> '{}: {}: {}'.format(2009, 4, day='Sunday')
'2009:4:Sunday'
```

The auto-numbering takes the fields from left to right, so the first `{ . . . }` specifier will use the first argument to `str.format()`, the next specifier will use the next argument, and so on. You can't mix auto-numbering and explicit numbering – either number all of your specifier fields or none of them – but you can mix auto-numbering and named fields, as in the second example above. (Contributed by Eric Smith; [issue 5237](#).)

Complex numbers now correctly support usage with `format()`, and default to being right-aligned. Specifying a precision or comma-separation applies to both the real and imaginary parts of the number, but a specified field width and alignment is applied to the whole of the resulting `1.5+3j` output. (Contributed by Eric Smith; [issue 1588](#) and [issue 7988](#).)

The 'F' format code now always formats its output using uppercase characters, so it will now produce 'INF' and 'NaN'. (Contributed by Eric Smith; [issue 3382](#).)

A low-level change: the `object.__format__()` method now triggers a `PendingDeprecationWarning` if it's passed a format string, because the `__format__()` method for `object` converts the object to a string representation and formats that. Previously the method silently applied the format string to the string representation, but that could hide mistakes in Python code. If you're supplying formatting information such as an alignment or precision, presumably you're expecting the formatting to be applied in some object-specific way. (Fixed by Eric Smith; [issue 7994](#).)

- The `int()` and `long()` types gained a `bit_length` method that returns the number of bits necessary to represent its argument in binary:

```
>>> n = 37
>>> bin(n)
'0b100101'
```

```

>>> n.bit_length()
6
>>> n = 2**123-1
>>> n.bit_length()
123
>>> (n+1).bit_length()
124

```

(Contributed by Fredrik Johansson and Victor Stinner; [issue 3439](#).)

- The `import` statement will no longer try an absolute import if a relative import (e.g. `from .os import sep`) fails. This fixes a bug, but could possibly break certain `import` statements that were only working by accident. (Fixed by Meador Inge; [issue 7902](#).)
- It's now possible for a subclass of the built-in `unicode` type to override the `__unicode__()` method. (Implemented by Victor Stinner; [issue 1583863](#).)
- The `bytearray` type's `translate()` method now accepts `None` as its first argument. (Fixed by Georg Brandl; [issue 4759](#).)
- When using `@classmethod` and `@staticmethod` to wrap methods as class or static methods, the wrapper object now exposes the wrapped function as their `__func__` attribute. (Contributed by Amaury Forgeot d'Arc, after a suggestion by George Sakkis; [issue 5982](#).)
- When a restricted set of attributes were set using `__slots__`, deleting an unset attribute would not raise `AttributeError` as you would expect. Fixed by Benjamin Peterson; [issue 7604](#).)
- Two new encodings are now supported: “cp720”, used primarily for Arabic text; and “cp858”, a variant of CP 850 that adds the euro symbol. (CP720 contributed by Alexander Belchenko and Amaury Forgeot d'Arc in [issue 1616979](#); CP858 contributed by Tim Hatch in [issue 8016](#).)
- The `file` object will now set the `filename` attribute on the `IOError` exception when trying to open a directory on POSIX platforms (noted by Jan Kaliszewski; [issue 4764](#)), and now explicitly checks for and forbids writing to read-only file objects instead of trusting the C library to catch and report the error (fixed by Stefan Krahn; [issue 5677](#)).
- The Python tokenizer now translates line endings itself, so the `compile()` built-in function now accepts code using any line-ending convention. Additionally, it no longer requires that the code end in a newline.
- Extra parentheses in function definitions are illegal in Python 3.x, meaning that you get a syntax error from `def f((x)): pass`. In Python3-warning mode, Python 2.7 will now warn about this odd usage. (Noted by James Lingard; [issue 7362](#).)
- It's now possible to create weak references to old-style class objects. New-style classes were always weak-referenceable. (Fixed by Antoine Pitrou; [issue 8268](#).)
- When a module object is garbage-collected, the module's dictionary is now only cleared if no one else is holding a reference to the dictionary ([issue 7140](#)).

## 9.1 Interpreter Changes

A new environment variable, `PYTHONWARNINGS`, allows controlling warnings. It should be set to a string containing warning settings, equivalent to those used with the `-W` switch, separated by commas. (Contributed by Brian Curtin; [issue 7301](#).)

For example, the following setting will print warnings every time they occur, but turn warnings from the `Cookie` module into an error. (The exact syntax for setting an environment variable varies across operating systems and shells.)

```
export PYTHONWARNINGS=all,error:::Cookie:0
```

## 9.2 Optimizations

Several performance enhancements have been added:

- A new opcode was added to perform the initial setup for `with` statements, looking up the `__enter__()` and `__exit__()` methods. (Contributed by Benjamin Peterson.)
- The garbage collector now performs better for one common usage pattern: when many objects are being allocated without deallocating any of them. This would previously take quadratic time for garbage collection, but now the number of full garbage collections is reduced as the number of objects on the heap grows. The new logic only performs a full garbage collection pass when the middle generation has been collected 10 times and when the number of survivor objects from the middle generation exceeds 10% of the number of objects in the oldest generation. (Suggested by Martin von Löwis and implemented by Antoine Pitrou; [issue 4074](#).)
- The garbage collector tries to avoid tracking simple containers which can't be part of a cycle. In Python 2.7, this is now true for tuples and dicts containing atomic types (such as ints, strings, etc.). Transitively, a dict containing tuples of atomic types won't be tracked either. This helps reduce the cost of each garbage collection by decreasing the number of objects to be considered and traversed by the collector. (Contributed by Antoine Pitrou; [issue 4688](#).)
- Long integers are now stored internally either in base  $2^{15}$  or in base  $2^{30}$ , the base being determined at build time. Previously, they were always stored in base  $2^{15}$ . Using base  $2^{30}$  gives significant performance improvements on 64-bit machines, but benchmark results on 32-bit machines have been mixed. Therefore, the default is to use base  $2^{30}$  on 64-bit machines and base  $2^{15}$  on 32-bit machines; on Unix, there's a new configure option `--enable-big-digits` that can be used to override this default.

Apart from the performance improvements this change should be invisible to end users, with one exception: for testing and debugging purposes there's a new structseq `sys.long_info` that provides information about the internal format, giving the number of bits per digit and the size in bytes of the C type used to store each digit:

```
>>> import sys
>>> sys.long_info
sys.long_info(bits_per_digit=30, sizeof_digit=4)
```

(Contributed by Mark Dickinson; [issue 4258](#).)

Another set of changes made long objects a few bytes smaller: 2 bytes smaller on 32-bit systems and 6 bytes on 64-bit. (Contributed by Mark Dickinson; [issue 5260](#).)

- The division algorithm for long integers has been made faster by tightening the inner loop, doing shifts instead of multiplications, and fixing an unnecessary extra iteration. Various benchmarks show speedups of between 50% and 150% for long integer divisions and modulo operations. (Contributed by Mark Dickinson; [issue 5512](#).) Bitwise operations are also significantly faster (initial patch by Gregory Smith; [issue 1087418](#)).
- The implementation of `%` checks for the left-side operand being a Python string and special-cases it; this results in a 1-3% performance increase for applications that frequently use `%` with strings, such as templating libraries. (Implemented by Collin Winter; [issue 5176](#).)
- List comprehensions with an `if` condition are compiled into faster bytecode. (Patch by Antoine Pitrou, backported to 2.7 by Jeffrey Yasskin; [issue 4715](#).)
- Converting an integer or long integer to a decimal string was made faster by special-casing base 10 instead of using a generalized conversion function that supports arbitrary bases. (Patch by Gawain Bolton; [issue 6713](#).)
- The `split()`, `replace()`, `rindex()`, `rpartition()`, and `rsplit()` methods of string-like types (strings, Unicode strings, and `bytearray` objects) now use a fast reverse-search algorithm instead of a character-by-character scan. This is sometimes faster by a factor of 10. (Added by Florent Xicluna; [issue 7462](#) and [issue 7622](#).)
- The `pickle` and `cPickle` modules now automatically intern the strings used for attribute names, reducing memory usage of the objects resulting from unpickling. (Contributed by Jake McGuire; [issue 5084](#).)

- The `cPickle` module now special-cases dictionaries, nearly halving the time required to pickle them. (Contributed by Collin Winter; [issue 5670](#).)

## 10 New and Improved Modules

As in every release, Python's standard library received a number of enhancements and bug fixes. Here's a partial list of the most notable changes, sorted alphabetically by module name. Consult the `Misc/NEWS` file in the source tree for a more complete list of changes, or look through the Subversion logs for all the details.

- The `bdb` module's base debugging class `Bdb` gained a feature for skipping modules. The constructor now takes an iterable containing glob-style patterns such as `django.*`; the debugger will not step into stack frames from a module that matches one of these patterns. (Contributed by Maru Newby after a suggestion by Senthil Kumaran; [issue 5142](#).)
- The `binascii` module now supports the buffer API, so it can be used with `memoryview` instances and other similar buffer objects. (Backported from 3.x by Florent Xicluna; [issue 7703](#).)
- Updated module: the `bsddb` module has been updated from 4.7.2devel9 to version 4.8.4 of the [pybsddb package](#). The new version features better Python 3.x compatibility, various bug fixes, and adds several new BerkeleyDB flags and methods. (Updated by Jesús Cea Avi3n; [issue 8156](#). The `pybsddb` changelog can be read at <http://hg.jcea.es/pybsddb/file/tip/ChangeLog>.)
- The `bz2` module's `BZ2File` now supports the context management protocol, so you can write with `bz2.BZ2File(...)` as `f:`. (Contributed by Hagen F3rstenau; [issue 3860](#).)
- New class: the `Counter` class in the `collections` module is useful for tallying data. `Counter` instances behave mostly like dictionaries but return zero for missing keys instead of raising a `KeyError`:

```
>>> from collections import Counter
>>> c = Counter()
>>> for letter in 'here is a sample of english text':
...     c[letter] += 1
...
>>> c
Counter({' ': 6, 'e': 5, 's': 3, 'a': 2, 'i': 2, 'h': 2,
'l': 2, 't': 2, 'g': 1, 'f': 1, 'm': 1, 'o': 1, 'n': 1,
'p': 1, 'r': 1, 'x': 1})
>>> c['e']
5
>>> c['z']
0
```

There are three additional `Counter` methods. `most_common()` returns the `N` most common elements and their counts. `elements()` returns an iterator over the contained elements, repeating each element as many times as its count. `subtract()` takes an iterable and subtracts one for each element instead of adding; if the argument is a dictionary or another `Counter`, the counts are subtracted.

```
>>> c.most_common(5)
[(' ', 6), ('e', 5), ('s', 3), ('a', 2), ('i', 2)]
>>> c.elements() ->
'a', 'a', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ',
'e', 'e', 'e', 'e', 'e', 'g', 'f', 'i', 'i',
'h', 'h', 'm', 'l', 'l', 'o', 'n', 'p', 's',
's', 's', 'r', 't', 't', 'x'
>>> c['e']
5
```

```
>>> c.subtract('very heavy on the letter e')
>>> c['e']      # Count is now lower
-1
```

Contributed by Raymond Hettinger; [issue 1696199](#).

New class: `OrderedDict` is described in the earlier section *PEP 372: Adding an Ordered Dictionary to collections*.

New method: The `deque` data type now has a `count()` method that returns the number of contained elements equal to the supplied argument `x`, and a `reverse()` method that reverses the elements of the deque in-place. `deque` also exposes its maximum length as the read-only `maxlen` attribute. (Both features added by Raymond Hettinger.)

The `namedtuple` class now has an optional `rename` parameter. If `rename` is true, field names that are invalid because they've been repeated or aren't legal Python identifiers will be renamed to legal names that are derived from the field's position within the list of fields:

```
>>> from collections import namedtuple
>>> T = namedtuple('T', ['field1', '$illegal', 'for', 'field2'], rename=True)
>>> T._fields
('field1', '_1', '_2', 'field2')
```

(Added by Raymond Hettinger; [issue 1818](#).)

Finally, the `Mapping` abstract base class now returns `NotImplemented` if a mapping is compared to another type that isn't a `Mapping`. (Fixed by Daniel Stutzbach; [issue 8729](#).)

- Constructors for the parsing classes in the `ConfigParser` module now take a `allow_no_value` parameter, defaulting to false; if true, options without values will be allowed. For example:

```
>>> import ConfigParser, StringIO
>>> sample_config = """
... [mysqld]
... user = mysql
... pid-file = /var/run/mysqld/mysqld.pid
... skip-bdb
... """
>>> config = ConfigParser.RawConfigParser(allow_no_value=True)
>>> config.readfp(StringIO.StringIO(sample_config))
>>> config.get('mysqld', 'user')
'mysql'
>>> print config.get('mysqld', 'skip-bdb')
None
>>> print config.get('mysqld', 'unknown')
Traceback (most recent call last):
...
NoOptionError: No option 'unknown' in section: 'mysqld'
```

(Contributed by Mats Kindahl; [issue 7005](#).)

- Deprecated function: `contextlib.nested()`, which allows handling more than one context manager with a single `with` statement, has been deprecated, because the `with` statement now supports multiple context managers.
- The `cookielib` module now ignores cookies that have an invalid version field, one that doesn't contain an integer value. (Fixed by John J. Lee; [issue 3924](#).)
- The `copy` module's `deepcopy()` function will now correctly copy bound instance methods. (Implemented by Robert Collins; [issue 1515](#).)

- The `ctypes` module now always converts `None` to a C `NULL` pointer for arguments declared as pointers. (Changed by Thomas Heller; [issue 4606](#).) The underlying `libffi` library has been updated to version 3.0.9, containing various fixes for different platforms. (Updated by Matthias Klose; [issue 8142](#).)
- New method: the `datetime` module's `timedelta` class gained a `total_seconds()` method that returns the number of seconds in the duration. (Contributed by Brian Quinlan; [issue 5788](#).)
- New method: the `Decimal` class gained a `from_float()` class method that performs an exact conversion of a floating-point number to a `Decimal`. This exact conversion strives for the closest decimal approximation to the floating-point representation's value; the resulting decimal value will therefore still include the inaccuracy, if any. For example, `Decimal.from_float(0.1)` returns `Decimal('0.1000000000000000055511151231257827021181583404541015625')`. (Implemented by Raymond Hettinger; [issue 4796](#).)

Comparing instances of `Decimal` with floating-point numbers now produces sensible results based on the numeric values of the operands. Previously such comparisons would fall back to Python's default rules for comparing objects, which produced arbitrary results based on their type. Note that you still cannot combine `Decimal` and floating-point in other operations such as addition, since you should be explicitly choosing how to convert between `float` and `Decimal`. (Fixed by Mark Dickinson; [issue 2531](#).)

The constructor for `Decimal` now accepts floating-point numbers (added by Raymond Hettinger; [issue 8257](#)) and non-European Unicode characters such as Arabic-Indic digits (contributed by Mark Dickinson; [issue 6595](#)).

Most of the methods of the `Context` class now accept integers as well as `Decimal` instances; the only exceptions are the `canonical()` and `is_canonical()` methods. (Patch by Juan José Conti; [issue 7633](#).)

When using `Decimal` instances with a string's `format()` method, the default alignment was previously left-alignment. This has been changed to right-alignment, which is more sensible for numeric types. (Changed by Mark Dickinson; [issue 6857](#).)

Comparisons involving a signaling NaN value (or `sNaN`) now signal `InvalidOperation` instead of silently returning a `true` or `false` value depending on the comparison operator. Quiet NaN values (or `NaN`) are now hashable. (Fixed by Mark Dickinson; [issue 7279](#).)

- The `difflib` module now produces output that is more compatible with modern **diff/patch** tools through one small change, using a tab character instead of spaces as a separator in the header giving the filename. (Fixed by Anatoly Techtonik; [issue 7585](#).)
- The Distutils `sdist` command now always regenerates the `MANIFEST` file, since even if the `MANIFEST.in` or `setup.py` files haven't been modified, the user might have created some new files that should be included. (Fixed by Tarek Ziade; [issue 8688](#).)
- The `doctest` module's `IGNORE_EXCEPTION_DETAIL` flag will now ignore the name of the module containing the exception being tested. (Patch by Lennart Regebro; [issue 7490](#).)
- The `email` module's `Message` class will now accept a Unicode-valued payload, automatically converting the payload to the encoding specified by `output_charset`. (Added by R. David Murray; [issue 1368247](#).)
- The `Fraction` class now accepts a single `float` or `Decimal` instance, or two rational numbers, as arguments to its constructor. (Implemented by Mark Dickinson; rationals added in [issue 5812](#), and float/decimal in [issue 8294](#).)

Ordering comparisons (`<`, `<=`, `>`, `>=`) between fractions and complex numbers now raise a `TypeError`. This fixes an oversight, making the `Fraction` match the other numeric types.

- New class: `FTP_TLS` in the `ftplib` module provides secure FTP connections using TLS encapsulation of authentication as well as subsequent control and data transfers. (Contributed by Giampaolo Rodola; [issue 2054](#).)

The `storbinary()` method for binary uploads can now restart uploads thanks to an added `reset` parameter (patch by Pablo Mouzo; [issue 6845](#).)

- New class decorator: `total_ordering()` in the `functools` module takes a class that defines an `__eq__()` method and one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`, and generates the missing comparison methods. Since the `__cmp__()` method is being deprecated in Python 3.x, this decorator makes it easier to define ordered classes. (Added by Raymond Hettinger; [issue 5479](#).)

New function: `cmp_to_key()` will take an old-style comparison function that expects two arguments and return a new callable that can be used as the `key` parameter to functions such as `sorted()`, `min()` and `max()`, etc. The primary intended use is to help with making code compatible with Python 3.x. (Added by Raymond Hettinger.)

- New function: the `gc` module's `is_tracked()` returns true if a given instance is tracked by the garbage collector, false otherwise. (Contributed by Antoine Pitrou; [issue 4688](#).)
- The `gzip` module's `GzipFile` now supports the context management protocol, so you can write with `gzip.GzipFile(...)` as `f:` (contributed by Hagen Fürstenau; [issue 3860](#)), and it now implements the `io.BufferedIOBase` ABC, so you can wrap it with `io.BufferedReader` for faster processing (contributed by Nir Aides; [issue 7471](#)). It's also now possible to override the modification time recorded in a gzipped file by providing an optional timestamp to the constructor. (Contributed by Jacques Frechet; [issue 4272](#).)

Files in `gzip` format can be padded with trailing zero bytes; the `gzip` module will now consume these trailing bytes. (Fixed by Tadek Pietraszek and Brian Curtin; [issue 2846](#).)

- New attribute: the `hashlib` module now has an `algorithms` attribute containing a tuple naming the supported algorithms. In Python 2.7, `hashlib.algorithms` contains `('md5', 'sha1', 'sha224', 'sha256', 'sha384', 'sha512')`. (Contributed by Carl Chenet; [issue 7418](#).)
- The default `HTTPResponse` class used by the `httplib` module now supports buffering, resulting in much faster reading of HTTP responses. (Contributed by Kristján Valur Jónsson; [issue 4879](#).)

The `HTTPConnection` and `HTTPSConnection` classes now support a `source_address` parameter, a `(host, port)` 2-tuple giving the source address that will be used for the connection. (Contributed by Eldon Ziegler; [issue 3972](#).)

- The `ihooks` module now supports relative imports. Note that `ihooks` is an older module for customizing imports, superseded by the `imputil` module added in Python 2.0. (Relative import support added by Neil Schemenauer.)
- The `imaplib` module now supports IPv6 addresses. (Contributed by Derek Morr; [issue 1655](#).)
- New function: the `inspect` module's `getcallargs()` takes a callable and its positional and keyword arguments, and figures out which of the callable's parameters will receive each argument, returning a dictionary mapping argument names to their values. For example:

```
>>> from inspect import getcallargs
>>> def f(a, b=1, *pos, **named):
...     pass
>>> getcallargs(f, 1, 2, 3)
{'a': 1, 'b': 2, 'pos': (3,), 'named': {}}
>>> getcallargs(f, a=2, x=4)
{'a': 2, 'b': 1, 'pos': (), 'named': {'x': 4}}
>>> getcallargs(f)
Traceback (most recent call last):
...
TypeError: f() takes at least 1 argument (0 given)
```

Contributed by George Sakkis; [issue 3135](#).

- Updated module: The `io` library has been upgraded to the version shipped with Python 3.1. For 3.1, the I/O library was entirely rewritten in C and is 2 to 20 times faster depending on the task being performed. The original Python version was renamed to the `_pyio` module.

One minor resulting change: the `io.TextIOBase` class now has an `errors` attribute giving the error setting used for encoding and decoding errors (one of `'strict'`, `'replace'`, `'ignore'`).

The `io.FileIO` class now raises an `OSError` when passed an invalid file descriptor. (Implemented by Benjamin Peterson; [issue 4991](#).) The `truncate()` method now preserves the file position; previously it would change the file position to the end of the new file. (Fixed by Pascal Chambon; [issue 6939](#).)

- New function: `itertools.compress(data, selectors)` takes two iterators. Elements of `data` are returned if the corresponding value in `selectors` is true:

```
itertools.compress('ABCDEF', [1,0,1,0,1,1]) =>
A, C, E, F
```

New function: `itertools.combinations_with_replacement(iter, r)` returns all the possible `r`-length combinations of elements from the iterable `iter`. Unlike `combinations()`, individual elements can be repeated in the generated combinations:

```
itertools.combinations_with_replacement('abc', 2) =>
('a', 'a'), ('a', 'b'), ('a', 'c'),
('b', 'b'), ('b', 'c'), ('c', 'c')
```

Note that elements are treated as unique depending on their position in the input, not their actual values.

The `itertools.count()` function now has a `step` argument that allows incrementing by values other than 1. `count()` also now allows keyword arguments, and using non-integer values such as floats or `Decimal` instances. (Implemented by Raymond Hettinger; [issue 5032](#).)

`itertools.combinations()` and `itertools.product()` previously raised `ValueError` for values of `r` larger than the input iterable. This was deemed a specification error, so they now return an empty iterator. (Fixed by Raymond Hettinger; [issue 4816](#).)

- Updated module: The `json` module was upgraded to version 2.0.9 of the `simplejson` package, which includes a C extension that makes encoding and decoding faster. (Contributed by Bob Ippolito; [issue 4136](#).)

To support the new `collections.OrderedDict` type, `json.load()` now has an optional `object_pairs_hook` parameter that will be called with any object literal that decodes to a list of pairs. (Contributed by Raymond Hettinger; [issue 5381](#).)

- The `mailbox` module's `Maildir` class now records the timestamp on the directories it reads, and only re-reads them if the modification time has subsequently changed. This improves performance by avoiding unneeded directory scans. (Fixed by A.M. Kuchling and Antoine Pitrou; [issue 1607951](#), [issue 6896](#).)
- New functions: the `math` module gained `erf()` and `erfc()` for the error function and the complementary error function, `expm1()` which computes  $e^{**x} - 1$  with more precision than using `exp()` and subtracting 1, `gamma()` for the Gamma function, and `lgamma()` for the natural log of the Gamma function. (Contributed by Mark Dickinson and nirinA raseliarison; [issue 3366](#).)
- The `multiprocessing` module's `Manager*` classes can now be passed a callable that will be called whenever a subprocess is started, along with a set of arguments that will be passed to the callable. (Contributed by lekma; [issue 5585](#).)

The `Pool` class, which controls a pool of worker processes, now has an optional `maxtasksperchild` parameter. Worker processes will perform the specified number of tasks and then exit, causing the `Pool` to start a new worker. This is useful if tasks may leak memory or other resources, or if some tasks will cause the worker to become very large. (Contributed by Charles Cazabon; [issue 6963](#).)

- The `nntplib` module now supports IPv6 addresses. (Contributed by Derek Morr; [issue 1664](#).)
- New functions: the `os` module wraps the following POSIX system calls: `getresgid()` and `getresuid()`, which return the real, effective, and saved GIDs and UIDs; `setresgid()` and `setresuid()`, which set real, effective, and saved GIDs and UIDs to new values; `initgroups()`, which initialize the group access list

for the current process. (GID/UID functions contributed by Travis H.; [issue 6508](#). Support for `initgroups` added by Jean-Paul Calderone; [issue 7333](#).)

The `os.fork()` function now re-initializes the import lock in the child process; this fixes problems on Solaris when `fork()` is called from a thread. (Fixed by Zsolt Cserna; [issue 7242](#).)

- In the `os.path` module, the `normpath()` and `abspath()` functions now preserve Unicode; if their input path is a Unicode string, the return value is also a Unicode string. (`normpath()` fixed by Matt Giuca in [issue 5827](#); `abspath()` fixed by Ezio Melotti in [issue 3426](#).)
- The `pydoc` module now has help for the various symbols that Python uses. You can now do `help('<<')` or `help('@')`, for example. (Contributed by David Laban; [issue 4739](#).)
- The `re` module's `split()`, `sub()`, and `subn()` now accept an optional *flags* argument, for consistency with the other functions in the module. (Added by Gregory P. Smith.)
- New function: `run_path()` in the `runpy` module will execute the code at a provided *path* argument. *path* can be the path of a Python source file (`example.py`), a compiled bytecode file (`example.pyc`), a directory (`./package/`), or a zip archive (`example.zip`). If a directory or zip path is provided, it will be added to the front of `sys.path` and the module `__main__` will be imported. It's expected that the directory or zip contains a `__main__.py`; if it doesn't, some other `__main__.py` might be imported from a location later in `sys.path`. This makes more of the machinery of `runpy` available to scripts that want to mimic the way Python's command line processes an explicit path name. (Added by Nick Coghlan; [issue 6816](#).)
- New function: in the `shutil` module, `make_archive()` takes a filename, archive type (zip or tar-format), and a directory path, and creates an archive containing the directory's contents. (Added by Tarek Ziadé.)

`shutil`'s `copyfile()` and `copytree()` functions now raise a `SpecialFileError` exception when asked to copy a named pipe. Previously the code would treat named pipes like a regular file by opening them for reading, and this would block indefinitely. (Fixed by Antoine Pitrou; [issue 3002](#).)

- The `signal` module no longer re-installs the signal handler unless this is truly necessary, which fixes a bug that could make it impossible to catch the `EINTR` signal robustly. (Fixed by Charles-Francois Natali; [issue 8354](#).)
- New functions: in the `site` module, three new functions return various site- and user-specific paths. `getsitepackages()` returns a list containing all global site-packages directories, `getusersitepackages()` returns the path of the user's site-packages directory, and `getuserbase()` returns the value of the `USER_BASE` environment variable, giving the path to a directory that can be used to store data. (Contributed by Tarek Ziadé; [issue 6693](#).)

The `site` module now reports exceptions occurring when the `sitecustomize` module is imported, and will no longer catch and swallow the `KeyboardInterrupt` exception. (Fixed by Victor Stinner; [issue 3137](#).)

- The `create_connection()` function gained a *source\_address* parameter, a `(host, port)` 2-tuple giving the source address that will be used for the connection. (Contributed by Eldon Ziegler; [issue 3972](#).)

The `recv_into()` and `recvfrom_into()` methods will now write into objects that support the buffer API, most usefully the `bytearray` and `memoryview` objects. (Implemented by Antoine Pitrou; [issue 8104](#).)

- The `SocketServer` module's `TCPServer` class now supports socket timeouts and disabling the Nagle algorithm. The `disable_nagle_algorithm` class attribute defaults to `False`; if overridden to be `True`, new request connections will have the `TCP_NODELAY` option set to prevent buffering many small sends into a single TCP packet. The `timeout` class attribute can hold a timeout in seconds that will be applied to the request socket; if no request is received within that time, `handle_timeout()` will be called and `handle_request()` will return. (Contributed by Kristján Valur Jónsson; [issue 6192](#) and [issue 6267](#).)
- Updated module: the `sqlite3` module has been updated to version 2.6.0 of the [pysqlite package](#). Version 2.6.0 includes a number of bugfixes, and adds the ability to load SQLite extensions from shared libraries. Call the `enable_load_extension(True)` method to enable extensions, and then call `load_extension()` to load a particular shared library. (Updated by Gerhard Häring.)

- The `ssl` module's `SSLSocket` objects now support the buffer API, which fixed a test suite failure (fix by Antoine Pitrou; [issue 7133](#)) and automatically set OpenSSL's `SSL_MODE_AUTO_RETRY`, which will prevent an error code being returned from `recv()` operations that trigger an SSL renegotiation (fix by Antoine Pitrou; [issue 8222](#)).

The `ssl.wrap_socket()` constructor function now takes a *ciphers* argument that's a string listing the encryption algorithms to be allowed; the format of the string is described in the [OpenSSL documentation](#). (Added by Antoine Pitrou; [issue 8322](#).)

Another change makes the extension load all of OpenSSL's ciphers and digest algorithms so that they're all available. Some SSL certificates couldn't be verified, reporting an "unknown algorithm" error. (Reported by Beda Kosata, and fixed by Antoine Pitrou; [issue 8484](#).)

The version of OpenSSL being used is now available as the module attributes `ssl.OPENSSL_VERSION` (a string), `ssl.OPENSSL_VERSION_INFO` (a 5-tuple), and `ssl.OPENSSL_VERSION_NUMBER` (an integer). (Added by Antoine Pitrou; [issue 8321](#).)

- The `struct` module will no longer silently ignore overflow errors when a value is too large for a particular integer format code (one of `bBhHiIlLqQ`); it now always raises a `struct.error` exception. (Changed by Mark Dickinson; [issue 1523](#).) The `pack()` function will also attempt to use `__index__()` to convert and pack non-integers before trying the `__int__()` method or reporting an error. (Changed by Mark Dickinson; [issue 8300](#).)
- New function: the `subprocess` module's `check_output()` runs a command with a specified set of arguments and returns the command's output as a string when the command runs without error, or raises a `CalledProcessError` exception otherwise.

```
>>> subprocess.check_output(['df', '-h', '.'])
'Filesystem      Size  Used Avail Capacity  Mounted on\n
/dev/disk0s2    52G   49G   3.0G   94%     /\n'
```

```
>>> subprocess.check_output(['df', '-h', '/bogus'])
```

```
...
subprocess.CalledProcessError: Command '['df', '-h', '/bogus']' returned non-zero exit
```

(Contributed by Gregory P. Smith.)

The `subprocess` module will now retry its internal system calls on receiving an `EINTR` signal. (Reported by several people; final patch by Gregory P. Smith in [issue 1068268](#).)

- New function: `is_declared_global()` in the `symtable` module returns true for variables that are explicitly declared to be global, false for ones that are implicitly global. (Contributed by Jeremy Hylton.)
- The `syslog` module will now use the value of `sys.argv[0]` as the identifier instead of the previous default value of `'python'`. (Changed by Sean Reifschneider; [issue 8451](#).)
- The `sys.version_info` value is now a named tuple, with attributes named `major`, `minor`, `micro`, `releaselevel`, and `serial`. (Contributed by Ross Light; [issue 4285](#).)

`sys.getwindowsversion()` also returns a named tuple, with attributes named `major`, `minor`, `build`, `platform`, `service_pack`, `service_pack_major`, `service_pack_minor`, `suite_mask`, and `product_type`. (Contributed by Brian Curtin; [issue 7766](#).)

- The `tarfile` module's default error handling has changed, to no longer suppress fatal errors. The default error level was previously 0, which meant that errors would only result in a message being written to the debug log, but because the debug log is not activated by default, these errors go unnoticed. The default error level is now 1, which raises an exception if there's an error. (Changed by Lars Gustäbel; [issue 7357](#).)

`tarfile` now supports filtering the `TarInfo` objects being added to a tar file. When you call `add()`, you may supply an optional *filter* argument that's a callable. The *filter* callable will be passed the `TarInfo` for every file being added, and can modify and return it. If the callable returns `None`, the file will be excluded

from the resulting archive. This is more powerful than the existing *exclude* argument, which has therefore been deprecated. (Added by Lars Gustäbel; [issue 6856](#).) The `TarFile` class also now supports the context manager protocol. (Added by Lars Gustäbel; [issue 7232](#).)

- The `wait()` method of the `threading.Event` class now returns the internal flag on exit. This means the method will usually return `true` because `wait()` is supposed to block until the internal flag becomes true. The return value will only be `false` if a timeout was provided and the operation timed out. (Contributed by Tim Leshner; [issue 1674032](#).)
- The Unicode database provided by the `unicodedata` module is now used internally to determine which characters are numeric, whitespace, or represent line breaks. The database also includes information from the `Unihan.txt` data file (patch by Anders Chrigström and Amaury Forgeot d'Arc; [issue 1571184](#)) and has been updated to version 5.2.0 (updated by Florent Xicluna; [issue 8024](#)).
- The `urlparse` module's `urlsplit()` now handles unknown URL schemes in a fashion compliant with [RFC 3986](#): if the URL is of the form "`<something>://...`", the text before the `://` is treated as the scheme, even if it's a made-up scheme that the module doesn't know about. This change may break code that worked around the old behaviour. For example, Python 2.6.4 or 2.5 will return the following:

```
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', '', '//host/filename?query', '', '')
```

Python 2.7 (and Python 2.6.5) will return:

```
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', 'host', '/filename?query', '', '')
```

(Python 2.7 actually produces slightly different output, since it returns a named tuple instead of a standard tuple.)

The `urlparse` module also supports IPv6 literal addresses as defined by

[RFC 2732](#) (contributed by Senthil Kumaran; [issue 2987](#)).

```
>>> urlparse.urlparse('http://[1080::8:800:200C:417A]/foo')
ParseResult(scheme='http', netloc='[1080::8:800:200C:417A]',
            path='/foo', params='', query='', fragment='')
```

- New class: the `WeakSet` class in the `weakref` module is a set that only holds weak references to its elements; elements will be removed once there are no references pointing to them. (Originally implemented in Python 3.x by Raymond Hettinger, and backported to 2.7 by Michael Foord.)
- The `ElementTree` library, `xml.etree`, no longer escapes ampersands and angle brackets when outputting an XML processing instruction (which looks like `<?xml-stylesheet href="#style1"?>`) or comment (which looks like `<!-- comment -->`). (Patch by Neil Muller; [issue 2746](#).)
- The XML-RPC client and server, provided by the `xmlrpclib` and `SimpleXMLRPCServer` modules, have improved performance by supporting HTTP/1.1 keep-alive and by optionally using `gzip` encoding to compress the XML being exchanged. The `gzip` compression is controlled by the `encode_threshold` attribute of `SimpleXMLRPCRequestHandler`, which contains a size in bytes; responses larger than this will be compressed. (Contributed by Kristján Valur Jónsson; [issue 6267](#).)
- The `zipfile` module's `ZipFile` now supports the context management protocol, so you can write with `zipfile.ZipFile(...)` as `f:.` (Contributed by Brian Curtin; [issue 5511](#).)

`zipfile` now also supports archiving empty directories and extracts them correctly. (Fixed by Kuba Wiczorek; [issue 4710](#).) Reading files out of an archive is faster, and interleaving `read()` and `readline()` now works correctly. (Contributed by Nir Aides; [issue 7610](#).)

The `is_zipfile()` function now accepts a file object, in addition to the path names accepted in earlier versions. (Contributed by Gabriel Genellina; [issue 4756](#).)

The `writestr()` method now has an optional `compress_type` parameter that lets you override the default compression method specified in the `ZipFile` constructor. (Contributed by Ronald Oussoren; [issue 6003](#).)

## 10.1 New module: `importlib`

Python 3.1 includes the `importlib` package, a re-implementation of the logic underlying Python's `import` statement. `importlib` is useful for implementors of Python interpreters and to users who wish to write new importers that can participate in the import process. Python 2.7 doesn't contain the complete `importlib` package, but instead has a tiny subset that contains a single function, `import_module()`.

`import_module(name, package=None)` imports a module. *name* is a string containing the module or package's name. It's possible to do relative imports by providing a string that begins with a `.` character, such as `..utils.errors`. For relative imports, the *package* argument must be provided and is the name of the package that will be used as the anchor for the relative import. `import_module()` both inserts the imported module into `sys.modules` and returns the module object.

Here are some examples:

```
>>> from importlib import import_module
>>> anydbm = import_module('anydbm') # Standard absolute import
>>> anydbm
<module 'anydbm' from '/p/python/Lib/anydbm.py'>
>>> # Relative import
>>> file_util = import_module('..file_util', 'distutils.command')
>>> file_util
<module 'distutils.file_util' from '/python/Lib/distutils/file_util.pyc'>
```

`importlib` was implemented by Brett Cannon and introduced in Python 3.1.

## 10.2 New module: `sysconfig`

The `sysconfig` module has been pulled out of the `Distutils` package, becoming a new top-level module in its own right. `sysconfig` provides functions for getting information about Python's build process: compiler switches, installation paths, the platform name, and whether Python is running from its source directory.

Some of the functions in the module are:

- `get_config_var()` returns variables from Python's Makefile and the `pyconfig.h` file.
- `get_config_vars()` returns a dictionary containing all of the configuration variables.
- `get_path()` returns the configured path for a particular type of module: the standard library, site-specific modules, platform-specific modules, etc.
- `is_python_build()` returns true if you're running a binary from a Python source tree, and false otherwise.

Consult the `sysconfig` documentation for more details and for a complete list of functions.

The `Distutils` package and `sysconfig` are now maintained by Tarek Ziadé, who has also started a `Distutils2` package (source repository at <http://hg.python.org/distutils2/>) for developing a next-generation version of `Distutils`.

## 10.3 `ttk`: Themed Widgets for Tk

Tcl/Tk 8.5 includes a set of themed widgets that re-implement basic Tk widgets but have a more customizable appearance and can therefore more closely resemble the native platform's widgets. This widget set was originally called `Tile`, but was renamed to `Ttk` (for “themed Tk”) on being added to Tcl/Tk release 8.5.

To learn more, read the `ttk` module documentation. You may also wish to read the Tcl/Tk manual page describing the Ttk theme engine, available at [http://www.tcl.tk/man/tcl8.5/TkCmd/ttk\\_intro.htm](http://www.tcl.tk/man/tcl8.5/TkCmd/ttk_intro.htm). Some screenshots of the Python/Ttk code in use are at <http://code.google.com/p/python-ttk/wiki/Screenshots>.

The `ttk` module was written by Guilherme Polo and added in [issue 2983](#). An alternate version called `Tile.py`, written by Martin Franklin and maintained by Kevin Walzer, was proposed for inclusion in [issue 2618](#), but the authors argued that Guilherme Polo's work was more comprehensive.

## 10.4 Updated module: unittest

The `unittest` module was greatly enhanced; many new features were added. Most of these features were implemented by Michael Foord, unless otherwise noted. The enhanced version of the module is downloadable separately for use with Python versions 2.4 to 2.6, packaged as the `unittest2` package, from <http://pypi.python.org/pypi/unittest2>.

When used from the command line, the module can automatically discover tests. It's not as fancy as `py.test` or `nose`, but provides a simple way to run tests kept within a set of package directories. For example, the following command will search the `test/` subdirectory for any importable test files named `test*.py`:

```
python -m unittest discover -s test
```

Consult the `unittest` module documentation for more details. (Developed in [issue 6001](#).)

The `main()` function supports some other new options:

- `-b` or `--buffer` will buffer the standard output and standard error streams during each test. If the test passes, any resulting output will be discarded; on failure, the buffered output will be displayed.
- `-c` or `--catch` will cause the control-C interrupt to be handled more gracefully. Instead of interrupting the test process immediately, the currently running test will be completed and then the partial results up to the interruption will be reported. If you're impatient, a second press of control-C will cause an immediate interruption.

This control-C handler tries to avoid causing problems when the code being tested or the tests being run have defined a signal handler of their own, by noticing that a signal handler was already set and calling it. If this doesn't work for you, there's a `removeHandler()` decorator that can be used to mark tests that should have the control-C handling disabled.

- `-f` or `--failfast` makes test execution stop immediately when a test fails instead of continuing to execute further tests. (Suggested by Cliff Dyer and implemented by Michael Foord; [issue 8074](#).)

The progress messages now show 'x' for expected failures and 'u' for unexpected successes when run in verbose mode. (Contributed by Benjamin Peterson.)

Test cases can raise the `SkipTest` exception to skip a test ([issue 1034053](#)).

The error messages for `assertEqual()`, `assertTrue()`, and `assertFalse()` failures now provide more information. If you set the `longMessage` attribute of your `TestCase` classes to `True`, both the standard error message and any additional message you provide will be printed for failures. (Added by Michael Foord; [issue 5663](#).)

The `assertRaises()` method now returns a context handler when called without providing a callable object to run. For example, you can write this:

```
with self.assertRaises(KeyError):  
    {}['foo']
```

(Implemented by Antoine Pitrou; [issue 4444](#).)

Module- and class-level setup and teardown fixtures are now supported. Modules can contain `setUpModule()` and `tearDownModule()` functions. Classes can have `setUpClass()` and `tearDownClass()` methods that must be defined as class methods (using `@classmethod` or equivalent). These functions and methods are invoked when the test runner switches to a test case in a different module or class.

The methods `addCleanup()` and `doCleanups()` were added. `addCleanup()` lets you add cleanup functions that will be called unconditionally (after `setUp()` if `setUp()` fails, otherwise after `tearDown()`). This allows for much simpler resource allocation and deallocation during tests ([issue 5679](#)).

A number of new methods were added that provide more specialized tests. Many of these methods were written by Google engineers for use in their test suites; Gregory P. Smith, Michael Foord, and GvR worked on merging them into Python's version of `unittest`.

- `assertIsNone()` and `assertIsNotNone()` take one expression and verify that the result is or is not `None`.
- `assertIs()` and `assertIsNot()` take two values and check whether the two values evaluate to the same object or not. (Added by Michael Foord; [issue 2578](#).)
- `assertIsInstance()` and `assertNotIsInstance()` check whether the resulting object is an instance of a particular class, or of one of a tuple of classes. (Added by Georg Brandl; [issue 7031](#).)
- `assertGreater()`, `assertGreaterEqual()`, `assertLess()`, and `assertLessEqual()` compare two quantities.
- `assertMultiLineEqual()` compares two strings, and if they're not equal, displays a helpful comparison that highlights the differences in the two strings. This comparison is now used by default when Unicode strings are compared with `assertEqual()`.
- `assertRegexpMatches()` and `assertNotRegexpMatches()` checks whether the first argument is a string matching or not matching the regular expression provided as the second argument ([issue 8038](#)).
- `assertRaisesRegexp()` checks whether a particular exception is raised, and then also checks that the string representation of the exception matches the provided regular expression.
- `assertIn()` and `assertNotIn()` tests whether *first* is or is not in *second*.
- `assertItemsEqual()` tests whether two provided sequences contain the same elements.
- `assertSetEqual()` compares whether two sets are equal, and only reports the differences between the sets in case of error.
- Similarly, `assertListEqual()` and `assertTupleEqual()` compare the specified types and explain any differences without necessarily printing their full values; these methods are now used by default when comparing lists and tuples using `assertEqual()`. More generally, `assertSequenceEqual()` compares two sequences and can optionally check whether both sequences are of a particular type.
- `assertDictEqual()` compares two dictionaries and reports the differences; it's now used by default when you compare two dictionaries using `assertEqual()`. `assertDictContainsSubset()` checks whether all of the key/value pairs in *first* are found in *second*.
- `assertAlmostEqual()` and `assertNotAlmostEqual()` test whether *first* and *second* are approximately equal. This method can either round their difference to an optionally-specified number of *places* (the default is 7) and compare it to zero, or require the difference to be smaller than a supplied *delta* value.
- `loadTestsFromName()` properly honors the `suiteClass` attribute of the `TestLoader`. (Fixed by Mark Roddy; [issue 6866](#).)
- A new hook lets you extend the `assertEqual()` method to handle new data types. The `addTypeEqualityFunc()` method takes a type object and a function. The function will be used when both of the objects being compared are of the specified type. This function should compare the two objects and raise an exception if they don't match; it's a good idea for the function to provide additional information about why the two objects aren't matching, much as the new sequence comparison methods do.

`unittest.main()` now takes an optional `exit` argument. If `False`, `main()` doesn't call `sys.exit()`, allowing `main()` to be used from the interactive interpreter. (Contributed by J. Pablo Fernández; [issue 3379](#).)

TestResult has new `startTestRun()` and `stopTestRun()` methods that are called immediately before and after a test run. (Contributed by Robert Collins; [issue 5728](#).)

With all these changes, the `unittest.py` was becoming awkwardly large, so the module was turned into a package and the code split into several files (by Benjamin Peterson). This doesn't affect how the module is imported or used.

#### See Also:

<http://www.voidspace.org.uk/python/articles/unittest2.shtml> Describes the new features, how to use them, and the rationale for various design decisions. (By Michael Foord.)

## 10.5 Updated module: ElementTree 1.3

The version of the ElementTree library included with Python was updated to version 1.3. Some of the new features are:

- The various parsing functions now take a `parser` keyword argument giving an `XMLParser` instance that will be used. This makes it possible to override the file's internal encoding:

```
p = ET.XMLParser(encoding='utf-8')
t = ET.XML("""<root/>""", parser=p)
```

Errors in parsing XML now raise a `ParseError` exception, whose instances have a `position` attribute containing a `(line, column)` tuple giving the location of the problem.

- ElementTree's code for converting trees to a string has been significantly reworked, making it roughly twice as fast in many cases. The `ElementTree.write()` and `Element.write()` methods now have a `method` parameter that can be "xml" (the default), "html", or "text". HTML mode will output empty elements as `<empty></empty>` instead of `<empty/>`, and text mode will skip over elements and only output the text chunks. If you set the `tag` attribute of an element to `None` but leave its children in place, the element will be omitted when the tree is written out, so you don't need to do more extensive rearrangement to remove a single element.

Namespace handling has also been improved. All `xmlns:<whatever>` declarations are now output on the root element, not scattered throughout the resulting XML. You can set the default namespace for a tree by setting the `default_namespace` attribute and can register new prefixes with `register_namespace()`. In XML mode, you can use the `true/false xml_declaration` parameter to suppress the XML declaration.

- New Element method: `extend()` appends the items from a sequence to the element's children. Elements themselves behave like sequences, so it's easy to move children from one element to another:

```
from xml.etree import ElementTree as ET

t = ET.XML("""<list>
  <item>1</item> <item>2</item> <item>3</item>
</list>""")
new = ET.XML('<root/>')
new.extend(t)

# Outputs <root><item>1</item>...</root>
print ET.tostring(new)
```

- New Element method: `iter()` yields the children of the element as a generator. It's also possible to write for `child in elem`: to loop over an element's children. The existing method `getiterator()` is now deprecated, as is `getchildren()` which constructs and returns a list of children.
- New Element method: `itertext()` yields all chunks of text that are descendants of the element. For example:

```
t = ET.XML("""<list>
  <item>1</item> <item>2</item> <item>3</item>
</list>""")

# Outputs ['\n ', '1', ' ', '2', ' ', '3', '\n']
print list(t.itertext())
```

- **Deprecated:** using an element as a Boolean (i.e., `if elem:`) would return true if the element had any children, or false if there were no children. This behaviour is confusing – None is false, but so is a childless element? – so it will now trigger a `FutureWarning`. In your code, you should be explicit: write `len(elem) != 0` if you're interested in the number of children, or `elem is not None`.

Fredrik Lundh develops `ElementTree` and produced the 1.3 version; you can read his article describing 1.3 at <http://effbot.org/zone/elementtree-13-intro.htm>. Florent Xicluna updated the version included with Python, after discussions on `python-dev` and in [issue 6472](#).)

## 11 Build and C API Changes

Changes to Python's build process and to the C API include:

- The latest release of the GNU Debugger, GDB 7, can be [scripted using Python](#). When you begin debugging an executable program `P`, GDB will look for a file named `P-gdb.py` and automatically read it. Dave Malcolm contributed a `python-gdb.py` that adds a number of commands useful when debugging Python itself. For example, `py-up` and `py-down` go up or down one Python stack frame, which usually corresponds to several C stack frames. `py-print` prints the value of a Python variable, and `py-bt` prints the Python stack trace. (Added as a result of [issue 8032](#).)
- If you use the `.gdbinit` file provided with Python, the “`pyo`” macro in the 2.7 version now works correctly when the thread being debugged doesn't hold the GIL; the macro now acquires it before printing. (Contributed by Victor Stinner; [issue 3632](#).)
- `Py_AddPendingCall()` is now thread-safe, letting any worker thread submit notifications to the main Python thread. This is particularly useful for asynchronous IO operations. (Contributed by Kristján Valur Jónsson; [issue 4293](#).)
- New function: `PyCode_NewEmpty()` creates an empty code object; only the filename, function name, and first line number are required. This is useful for extension modules that are attempting to construct a more useful traceback stack. Previously such extensions needed to call `PyCode_New()`, which had many more arguments. (Added by Jeffrey Yasskin.)
- New function: `PyErr_NewExceptionWithDoc()` creates a new exception class, just as the existing `PyErr_NewException()` does, but takes an extra `char *` argument containing the docstring for the new exception class. (Added by 'lekma' on the Python bug tracker; [issue 7033](#).)
- New function: `PyFrame_GetLineNumber()` takes a frame object and returns the line number that the frame is currently executing. Previously code would need to get the index of the bytecode instruction currently executing, and then look up the line number corresponding to that address. (Added by Jeffrey Yasskin.)
- New functions: `PyLong_AsLongAndOverflow()` and `PyLong_AsLongLongAndOverflow()` approximates a Python long integer as a C long or long long. If the number is too large to fit into the output type, an *overflow* flag is set and returned to the caller. (Contributed by Case Van Horses; [issue 7528](#) and [issue 7767](#).)
- New function: stemming from the rewrite of string-to-float conversion, a new `PyOS_string_to_double()` function was added. The old `PyOS_ascii_strtod()` and `PyOS_ascii_atof()` functions are now deprecated.

- New function: `PySys_SetArgvEx()` sets the value of `sys.argv` and can optionally update `sys.path` to include the directory containing the script named by `sys.argv[0]` depending on the value of an *updatepath* parameter.

This function was added to close a security hole for applications that embed Python. The old function, `PySys_SetArgv()`, would always update `sys.path`, and sometimes it would add the current directory. This meant that, if you ran an application embedding Python in a directory controlled by someone else, attackers could put a Trojan-horse module in the directory (say, a file named `os.py`) that your application would then import and run.

If you maintain a C/C++ application that embeds Python, check whether you're calling `PySys_SetArgv()` and carefully consider whether the application should be using `PySys_SetArgvEx()` with *updatepath* set to false.

Security issue reported as [CVE-2008-5983](#); discussed in [issue 5753](#), and fixed by Antoine Pitrou.

- New macros: the Python header files now define the following macros: `Py_ISALNUM`, `Py_ISALPHA`, `Py_ISDIGIT`, `Py_ISLOWER`, `Py_ISSPACE`, `Py_ISUPPER`, `Py_ISXDIGIT`, `Py_TOLOWER`, and `Py_TOUPPER`. All of these functions are analogous to the C standard macros for classifying characters, but ignore the current locale setting, because in several places Python needs to analyze characters in a locale-independent way. (Added by Eric Smith; [issue 5793](#).)
- Removed function: `PyEval_CallObject` is now only available as a macro. A function version was being kept around to preserve ABI linking compatibility, but that was in 1997; it can certainly be deleted by now. (Removed by Antoine Pitrou; [issue 8276](#).)
- New format codes: the `PyFormat_FromString()`, `PyFormat_FromStringV()`, and `PyErr_Format()` functions now accept `%lld` and `%llu` format codes for displaying C's long long types. (Contributed by Mark Dickinson; [issue 7228](#).)
- The complicated interaction between threads and process forking has been changed. Previously, the child process created by `os.fork()` might fail because the child is created with only a single thread running, the thread performing the `os.fork()`. If other threads were holding a lock, such as Python's import lock, when the fork was performed, the lock would still be marked as "held" in the new process. But in the child process nothing would ever release the lock, since the other threads weren't replicated, and the child process would no longer be able to perform imports.

Python 2.7 acquires the import lock before performing an `os.fork()`, and will also clean up any locks created using the `threading` module. C extension modules that have internal locks, or that call `fork()` themselves, will not benefit from this clean-up.

(Fixed by Thomas Wouters; [issue 1590864](#).)

- The `Py_Finalize()` function now calls the internal `threading._shutdown()` function; this prevents some exceptions from being raised when an interpreter shuts down. (Patch by Adam Olsen; [issue 1722344](#).)
- When using the `PyMemberDef` structure to define attributes of a type, Python will no longer let you try to delete or set a `T_STRING_INPLACE` attribute.
- Global symbols defined by the `ctypes` module are now prefixed with `Py`, or with `_ctypes`. (Implemented by Thomas Heller; [issue 3102](#).)
- New configure option: the `--with-system-expat` switch allows building the `pyexpat` module to use the system Expat library. (Contributed by Arfrever Frehtes Taifersar Arahesis; [issue 7609](#).)
- New configure option: the `--with-valgrind` option will now disable the `pymalloc` allocator, which is difficult for the Valgrind memory-error detector to analyze correctly. Valgrind will therefore be better at detecting memory leaks and overruns. (Contributed by James Henstridge; [issue 2422](#).)
- New configure option: you can now supply an empty string to `--with-dbmliborder=` in order to disable all of the various DBM modules. (Added by Arfrever Frehtes Taifersar Arahesis; [issue 6491](#).)

- The **configure** script now checks for floating-point rounding bugs on certain 32-bit Intel chips and defines a `X87_DOUBLE_ROUNDING` preprocessor definition. No code currently uses this definition, but it's available if anyone wishes to use it. (Added by Mark Dickinson; [issue 2937](#).)

**configure** also now sets a `LDCXXSHARED` Makefile variable for supporting C++ linking. (Contributed by Arfrever Frehtes Taifersar Arahesis; [issue 1222585](#).)

- The build process now creates the necessary files for pkg-config support. (Contributed by Clinton Roy; [issue 3585](#).)
- The build process now supports Subversion 1.7. (Contributed by Arfrever Frehtes Taifersar Arahesis; [issue 6094](#).)

## 11.1 Capsules

Python 3.1 adds a new C datatype, `PyCapsule`, for providing a C API to an extension module. A capsule is essentially the holder of a C `void *` pointer, and is made available as a module attribute; for example, the `socket` module's API is exposed as `socket.CAPI`, and `unicodedata` exposes `ucnhash_CAPI`. Other extensions can import the module, access its dictionary to get the capsule object, and then get the `void *` pointer, which will usually point to an array of pointers to the module's various API functions.

There is an existing data type already used for this, `PyObject`, but it doesn't provide type safety. Evil code written in pure Python could cause a segmentation fault by taking a `PyObject` from module A and somehow substituting it for the `PyObject` in module B. Capsules know their own name, and getting the pointer requires providing the name:

```
void *vtable;

if (!PyCapsule_IsValid(capsule, "mymodule.CAPI") {
    PyErr_SetString(PyExc_ValueError, "argument type invalid");
    return NULL;
}

vtable = PyCapsule_GetPointer(capsule, "mymodule.CAPI");
```

You are assured that `vtable` points to whatever you're expecting. If a different capsule was passed in, `PyCapsule_IsValid()` would detect the mismatched name and return false. Refer to *using-capsules* for more information on using these objects.

Python 2.7 now uses capsules internally to provide various extension-module APIs, but the `PyObject_AsVoidPtr()` was modified to handle capsules, preserving compile-time compatibility with the `CObject` interface. Use of `PyObject_AsVoidPtr()` will signal a `PendingDeprecationWarning`, which is silent by default.

Implemented in Python 3.1 and backported to 2.7 by Larry Hastings; discussed in [issue 5630](#).

## 11.2 Port-Specific Changes: Windows

- The `msvcrt` module now contains some constants from the `crtassem.h` header file: `CRT_ASSEMBLY_VERSION`, `VC_ASSEMBLY_PUBLICKEYTOKEN`, and `LIBRARIES_ASSEMBLY_NAME_PREFIX`. (Contributed by David Cournapeau; [issue 4365](#).)
- The `_winreg` module for accessing the registry now implements the `CreateKeyEx()` and `DeleteKeyEx()` functions, extended versions of previously-supported functions that take several extra arguments. The `DisableReflectionKey()`, `EnableReflectionKey()`, and `QueryReflectionKey()` were also tested and documented. (Implemented by Brian Curtin; [issue 7347](#).)

- The new `_beginthreadex()` API is used to start threads, and the native thread-local storage functions are now used. (Contributed by Kristján Valur Jónsson; [issue 3582](#).)
- The `os.kill()` function now works on Windows. The signal value can be the constants `CTRL_C_EVENT`, `CTRL_BREAK_EVENT`, or any integer. The first two constants will send Control-C and Control-Break keystroke events to subprocesses; any other value will use the `TerminateProcess()` API. (Contributed by Miki Tebeka; [issue 1220212](#).)
- The `os.listdir()` function now correctly fails for an empty path. (Fixed by Hirokazu Yamamoto; [issue 5913](#).)
- The `mimelib` module will now read the MIME database from the Windows registry when initializing. (Patch by Gabriel Genellina; [issue 4969](#).)

### 11.3 Port-Specific Changes: Mac OS X

- The path `/Library/Python/2.7/site-packages` is now appended to `sys.path`, in order to share added packages between the system installation and a user-installed copy of the same version. (Changed by Ronald Oussoren; [issue 4865](#).)

### 11.4 Port-Specific Changes: FreeBSD

- FreeBSD 7.1's `SO_SETFIB` constant, used with `getsockopt()/setsockopt()` to select an alternate routing table, is now available in the `socket` module. (Added by Kyle VanderBeek; [issue 8235](#).)

## 12 Other Changes and Fixes

- Two benchmark scripts, `iobench` and `ccbench`, were added to the `Tools` directory. `iobench` measures the speed of the built-in file I/O objects returned by `open()` while performing various operations, and `ccbench` is a concurrency benchmark that tries to measure computing throughput, thread switching latency, and IO processing bandwidth when performing several tasks using a varying number of threads.
- The `Tools/i18n/msgfmt.py` script now understands plural forms in `.po` files. (Fixed by Martin von Löwis; [issue 5464](#).)
- When importing a module from a `.pyc` or `.pyo` file with an existing `.py` counterpart, the `co_filename` attributes of the resulting code objects are overwritten when the original filename is obsolete. This can happen if the file has been renamed, moved, or is accessed through different paths. (Patch by Ziga Seilnacht and Jean-Paul Calderone; [issue 1180193](#).)
- The `regtest.py` script now takes a `--randseed=` switch that takes an integer that will be used as the random seed for the `-r` option that executes tests in random order. The `-r` option also reports the seed that was used (Added by Collin Winter.)
- Another `regtest.py` switch is `-j`, which takes an integer specifying how many tests run in parallel. This allows reducing the total runtime on multi-core machines. This option is compatible with several other options, including the `-R` switch which is known to produce long runtimes. (Added by Antoine Pitrou; [issue 6152](#).) This can also be used with a new `-F` switch that runs selected tests in a loop until they fail. (Added by Antoine Pitrou; [issue 7312](#).)
- When executed as a script, the `py_compile.py` module now accepts `'-'` as an argument, which will read standard input for the list of filenames to be compiled. (Contributed by Piotr Ożarowski; [issue 8233](#).)

## 13 Porting to Python 2.7

This section lists previously described changes and other bugfixes that may require changes to your code:

- The `range()` function processes its arguments more consistently; it will now call `__int__()` on non-float, non-integer arguments that are supplied to it. (Fixed by Alexander Belopolsky; [issue 1533](#).)
- The string `format()` method changed the default precision used for floating-point and complex numbers from 6 decimal places to 12, which matches the precision used by `str()`. (Changed by Eric Smith; [issue 5920](#).)
- Because of an optimization for the `with` statement, the special methods `__enter__()` and `__exit__()` must belong to the object's type, and cannot be directly attached to the object's instance. This affects new-style classes (derived from `object`) and C extension types. ([issue 6101](#).)
- Due to a bug in Python 2.6, the `exc_value` parameter to `__exit__()` methods was often the string representation of the exception, not an instance. This was fixed in 2.7, so `exc_value` will be an instance as expected. (Fixed by Florent Xicluna; [issue 7853](#).)
- When a restricted set of attributes were set using `__slots__`, deleting an unset attribute would not raise `AttributeError` as you would expect. Fixed by Benjamin Peterson; [issue 7604](#).)

In the standard library:

- Operations with `datetime` instances that resulted in a year falling outside the supported range didn't always raise `OverflowError`. Such errors are now checked more carefully and will now raise the exception. (Reported by Mark Leander, patch by Anand B. Pillai and Alexander Belopolsky; [issue 7150](#).)
- When using `Decimal` instances with a string's `format()` method, the default alignment was previously left-alignment. This has been changed to right-alignment, which might change the output of your programs. (Changed by Mark Dickinson; [issue 6857](#).)

Comparisons involving a signaling NaN value (or `sNaN`) now signal `InvalidOperation` instead of silently returning a true or false value depending on the comparison operator. Quiet NaN values (or `NaN`) are now hashable. (Fixed by Mark Dickinson; [issue 7279](#).)

- The `ElementTree` library, `xml.etree`, no longer escapes ampersands and angle brackets when outputting an XML processing instruction (which looks like `<?xml-stylesheet href="#style1"?>`) or comment (which looks like `<!-- comment -->`). (Patch by Neil Muller; [issue 2746](#).)
- The `readline()` method of `StringIO` objects now does nothing when a negative length is requested, as other file-like objects do. ([issue 7348](#).)
- The `syslog` module will now use the value of `sys.argv[0]` as the identifier instead of the previous default value of `'python'`. (Changed by Sean Reifschneider; [issue 8451](#).)
- The `tarfile` module's default error handling has changed, to no longer suppress fatal errors. The default error level was previously 0, which meant that errors would only result in a message being written to the debug log, but because the debug log is not activated by default, these errors go unnoticed. The default error level is now 1, which raises an exception if there's an error. (Changed by Lars Gustäbel; [issue 7357](#).)
- The `urlparse` module's `urlsplit()` now handles unknown URL schemes in a fashion compliant with [RFC 3986](#): if the URL is of the form "`<something>://...`", the text before the `://` is treated as the scheme, even if it's a made-up scheme that the module doesn't know about. This change may break code that worked around the old behaviour. For example, Python 2.6.4 or 2.5 will return the following:

```
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', '', '//host/filename?query', '', '')
```

Python 2.7 (and Python 2.6.5) will return:

```
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', 'host', '/filename?query', '', '')
```

(Python 2.7 actually produces slightly different output, since it returns a named tuple instead of a standard tuple.)

For C extensions:

- C extensions that use integer format codes with the `PyArg_Parse*` family of functions will now raise a `TypeError` exception instead of triggering a `DeprecationWarning` (issue 5080).
- Use the new `PyOS_string_to_double()` function instead of the old `PyOS_ascii_strtod()` and `PyOS_ascii_atof()` functions, which are now deprecated.

For applications that embed Python:

- The `PySys_SetArgvEx()` function was added, letting applications close a security hole when the existing `PySys_SetArgv()` function was used. Check whether you're calling `PySys_SetArgv()` and carefully consider whether the application should be using `PySys_SetArgvEx()` with *updatepath* set to false.

## 14 Acknowledgements

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# Installing Python Modules

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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**Author** Greg Ward

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**Abstract**

This document describes the Python Distribution Utilities (“Distutils”) from the end-user’s point-of-view, describing how to extend the capabilities of a standard Python installation by building and installing third-party Python modules and extensions.



# INTRODUCTION

Although Python's extensive standard library covers many programming needs, there often comes a time when you need to add some new functionality to your Python installation in the form of third-party modules. This might be necessary to support your own programming, or to support an application that you want to use and that happens to be written in Python.

In the past, there has been little support for adding third-party modules to an existing Python installation. With the introduction of the Python Distribution Utilities (Distutils for short) in Python 2.0, this changed.

This document is aimed primarily at the people who need to install third-party Python modules: end-users and system administrators who just need to get some Python application running, and existing Python programmers who want to add some new goodies to their toolbox. You don't need to know Python to read this document; there will be some brief forays into using Python's interactive mode to explore your installation, but that's it. If you're looking for information on how to distribute your own Python modules so that others may use them, see the *distutils-index* manual.

## 1.1 Best case: trivial installation

In the best case, someone will have prepared a special version of the module distribution you want to install that is targeted specifically at your platform and is installed just like any other software on your platform. For example, the module developer might make an executable installer available for Windows users, an RPM package for users of RPM-based Linux systems (Red Hat, SuSE, Mandrake, and many others), a Debian package for users of Debian-based Linux systems, and so forth.

In that case, you would download the installer appropriate to your platform and do the obvious thing with it: run it if it's an executable installer, `rpm --install` if it's an RPM, etc. You don't need to run Python or a setup script, you don't need to compile anything—you might not even need to read any instructions (although it's always a good idea to do so anyway).

Of course, things will not always be that easy. You might be interested in a module distribution that doesn't have an easy-to-use installer for your platform. In that case, you'll have to start with the source distribution released by the module's author/maintainer. Installing from a source distribution is not too hard, as long as the modules are packaged in the standard way. The bulk of this document is about building and installing modules from standard source distributions.

## 1.2 The new standard: Distutils

If you download a module source distribution, you can tell pretty quickly if it was packaged and distributed in the standard way, i.e. using the Distutils. First, the distribution's name and version number will be featured prominently in the name of the downloaded archive, e.g. `foo-1.0.tar.gz` or `widget-0.9.7.zip`. Next, the archive will unpack into a similarly-named directory: `foo-1.0` or `widget-0.9.7`. Additionally, the distribution will contain a

setup script `setup.py`, and a file named `README.txt` or possibly just `README`, which should explain that building and installing the module distribution is a simple matter of running one command from a terminal:

```
python setup.py install
```

For Windows, this command should be run from a command prompt window (*Start* → *Accessories*):

```
setup.py install
```

If all these things are true, then you already know how to build and install the modules you've just downloaded: Run the command above. Unless you need to install things in a non-standard way or customize the build process, you don't really need this manual. Or rather, the above command is everything you need to get out of this manual.

# STANDARD BUILD AND INSTALL

As described in section *The new standard: Distutils*, building and installing a module distribution using the Distutils is usually one simple command to run from a terminal:

```
python setup.py install
```

## 2.1 Platform variations

You should always run the `setup` command from the distribution root directory, i.e. the top-level subdirectory that the module source distribution unpacks into. For example, if you've just downloaded a module source distribution `foo-1.0.tar.gz` onto a Unix system, the normal thing to do is:

```
gunzip -c foo-1.0.tar.gz | tar xf - # unpacks into directory foo-1.0
cd foo-1.0
python setup.py install
```

On Windows, you'd probably download `foo-1.0.zip`. If you downloaded the archive file to `C:\Temp`, then it would unpack into `C:\Temp\foo-1.0`; you can use either a archive manipulator with a graphical user interface (such as WinZip) or a command-line tool (such as **unzip** or **pkunzip**) to unpack the archive. Then, open a command prompt window and run:

```
cd c:\Temp\foo-1.0
python setup.py install
```

## 2.2 Splitting the job up

Running `setup.py install` builds and installs all modules in one run. If you prefer to work incrementally—especially useful if you want to customize the build process, or if things are going wrong—you can use the `setup` script to do one thing at a time. This is particularly helpful when the build and install will be done by different users—for example, you might want to build a module distribution and hand it off to a system administrator for installation (or do it yourself, with super-user privileges).

For example, you can build everything in one step, and then install everything in a second step, by invoking the `setup` script twice:

```
python setup.py build
python setup.py install
```

If you do this, you will notice that running the **install** command first runs the **build** command, which—in this case—quickly notices that it has nothing to do, since everything in the `build` directory is up-to-date.

You may not need this ability to break things down often if all you do is install modules downloaded off the ‘net, but it’s very handy for more advanced tasks. If you get into distributing your own Python modules and extensions, you’ll run lots of individual Distutils commands on their own.

### 2.3 How building works

As implied above, the **build** command is responsible for putting the files to install into a *build directory*. By default, this is `build` under the distribution root; if you’re excessively concerned with speed, or want to keep the source tree pristine, you can change the build directory with the `--build-base` option. For example:

```
python setup.py build --build-base=/tmp/pybuild/foo-1.0
```

(Or you could do this permanently with a directive in your system or personal Distutils configuration file; see section *Distutils Configuration Files*.) Normally, this isn’t necessary.

The default layout for the build tree is as follows:

```
--- build/ --- lib/
or
--- build/ --- lib.<plat>/
                temp.<plat>/
```

where `<plat>` expands to a brief description of the current OS/hardware platform and Python version. The first form, with just a `lib` directory, is used for “pure module distributions”—that is, module distributions that include only pure Python modules. If a module distribution contains any extensions (modules written in C/C++), then the second form, with two `<plat>` directories, is used. In that case, the `temp.<plat>` directory holds temporary files generated by the compile/link process that don’t actually get installed. In either case, the `lib` (or `lib.<plat>`) directory contains all Python modules (pure Python and extensions) that will be installed.

In the future, more directories will be added to handle Python scripts, documentation, binary executables, and whatever else is needed to handle the job of installing Python modules and applications.

### 2.4 How installation works

After the **build** command runs (whether you run it explicitly, or the **install** command does it for you), the work of the **install** command is relatively simple: all it has to do is copy everything under `build/lib` (or `build/lib.<plat>`) to your chosen installation directory.

If you don’t choose an installation directory—i.e., if you just run `setup.py install`—then the **install** command installs to the standard location for third-party Python modules. This location varies by platform and by how you built/installed Python itself. On Unix (and Mac OS X, which is also Unix-based), it also depends on whether the module distribution being installed is pure Python or contains extensions (“non-pure”):

Platform	Standard installation location	Default value	Notes
Unix (pure)	<code>prefix/lib/pythonX.Y/site-packages</code>	<code>/usr/local/lib/pythonX.Y/site-packages</code>	(1)
Unix (non-pure)	<code>exec-prefix/lib/pythonX.Y/site-packages</code>	<code>/usr/local/lib/pythonX.Y/site-packages</code>	(1)
Windows	<code>prefix\Lib\site-packages</code>	<code>C:\PythonXY\Lib\site-packages</code>	(2)

Notes:

1. Most Linux distributions include Python as a standard part of the system, so `prefix` and `exec-prefix` are usually both `/usr` on Linux. If you build Python yourself on Linux (or any Unix-like system), the default `prefix` and `exec-prefix` are `/usr/local`.

2. The default installation directory on Windows was `C:\Program Files\Python` under Python 1.6a1, 1.5.2, and earlier.

`prefix` and `exec-prefix` stand for the directories that Python is installed to, and where it finds its libraries at run-time. They are always the same under Windows, and very often the same under Unix and Mac OS X. You can find out what your Python installation uses for `prefix` and `exec-prefix` by running Python in interactive mode and typing a few simple commands. Under Unix, just type `python` at the shell prompt. Under Windows, choose *Start* → *Programs* → *Python X.Y* → *Python (command line)*. Once the interpreter is started, you type Python code at the prompt. For example, on my Linux system, I type the three Python statements shown below, and get the output as shown, to find out my `prefix` and `exec-prefix`:

```
Python 2.4 (#26, Aug 7 2004, 17:19:02)
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys.prefix
'/usr'
>>> sys.exec_prefix
'/usr'
```

A few other placeholders are used in this document: `X.Y` stands for the version of Python, for example 2.7; `distname` will be replaced by the name of the module distribution being installed. Dots and capitalization are important in the paths; for example, a value that uses `python2.7` on UNIX will typically use `Python27` on Windows.

If you don't want to install modules to the standard location, or if you don't have permission to write there, then you need to read about alternate installations in section [Alternate Installation](#). If you want to customize your installation directories more heavily, see section [Custom Installation](#) on custom installations.



# ALTERNATE INSTALLATION

Often, it is necessary or desirable to install modules to a location other than the standard location for third-party Python modules. For example, on a Unix system you might not have permission to write to the standard third-party module directory. Or you might wish to try out a module before making it a standard part of your local Python installation. This is especially true when upgrading a distribution already present: you want to make sure your existing base of scripts still works with the new version before actually upgrading.

The Distutils **install** command is designed to make installing module distributions to an alternate location simple and painless. The basic idea is that you supply a base directory for the installation, and the **install** command picks a set of directories (called an *installation scheme*) under this base directory in which to install files. The details differ across platforms, so read whichever of the following sections applies to you.

Note that the various alternate installation schemes are mutually exclusive: you can pass `--user`, or `--home`, or `--prefix` and `--exec-prefix`, or `--install-base` and `--install-platbase`, but you can't mix from these groups.

## 3.1 Alternate installation: the user scheme

This scheme is designed to be the most convenient solution for users that don't have write permission to the global `site-packages` directory or don't want to install into it. It is enabled with a simple option:

```
python setup.py install --user
```

Files will be installed into subdirectories of `site.USER_BASE` (written as `userbase` hereafter). This scheme installs pure Python modules and extension modules in the same location (also known as `site.USER_SITE`). Here are the values for UNIX, including Mac OS X:

Type of file	Installation directory
modules	<code>userbase/lib/pythonX.Y/site-packages</code>
scripts	<code>userbase/bin</code>
data	<code>userbase</code>
C headers	<code>userbase/include/pythonX.Y/distname</code>

And here are the values used on Windows:

Type of file	Installation directory
modules	<code>userbase\PythonXY\site-packages</code>
scripts	<code>userbase\Scripts</code>
data	<code>userbase</code>
C headers	<code>userbase\PythonXY\Include\distname</code>

The advantage of using this scheme compared to the other ones described below is that the user `site-packages` directory is under normal conditions always included in `sys.path` (see `site` for more information), which means that there

is no additional step to perform after running the `setup.py` script to finalize the installation.

The `build_ext` command also has a `--user` option to add `userbase/include` to the compiler search path for header files and `userbase/lib` to the compiler search path for libraries as well as to the runtime search path for shared C libraries (`rpath`).

### 3.2 Alternate installation: the home scheme

The idea behind the “home scheme” is that you build and maintain a personal stash of Python modules. This scheme’s name is derived from the idea of a “home” directory on Unix, since it’s not unusual for a Unix user to make their home directory have a layout similar to `/usr/` or `/usr/local/`. This scheme can be used by anyone, regardless of the operating system they are installing for.

Installing a new module distribution is as simple as

```
python setup.py install --home=<dir>
```

where you can supply any directory you like for the `--home` option. On Unix, lazy typists can just type a tilde (`~`); the `install` command will expand this to your home directory:

```
python setup.py install --home=~
```

To make Python find the distributions installed with this scheme, you may have to *modify Python’s search path* or edit `sitecustomize` (see `site`) to call `site.addsitedir()` or edit `sys.path`.

The `--home` option defines the installation base directory. Files are installed to the following directories under the installation base as follows:

Type of file	Installation directory
modules	home/lib/python
scripts	home/bin
data	home
C headers	home/include/python/distname

(Mentally replace slashes with backslashes if you’re on Windows.) Changed in version 2.4: The `--home` option used to be supported only on Unix.

### 3.3 Alternate installation: Unix (the prefix scheme)

The “prefix scheme” is useful when you wish to use one Python installation to perform the build/install (i.e., to run the setup script), but install modules into the third-party module directory of a different Python installation (or something that looks like a different Python installation). If this sounds a trifle unusual, it is—that’s why the user and home schemes come before. However, there are at least two known cases where the prefix scheme will be useful.

First, consider that many Linux distributions put Python in `/usr`, rather than the more traditional `/usr/local`. This is entirely appropriate, since in those cases Python is part of “the system” rather than a local add-on. However, if you are installing Python modules from source, you probably want them to go in `/usr/local/lib/python2.X` rather than `/usr/lib/python2.X`. This can be done with

```
/usr/bin/python setup.py install --prefix=/usr/local
```

Another possibility is a network filesystem where the name used to write to a remote directory is different from the name used to read it: for example, the Python interpreter accessed as `/usr/local/bin/python` might search for modules in `/usr/local/lib/python2.X`, but those modules would have to be installed to, say, `/mnt/@server/export/lib/python2.X`. This could be done with

```
/usr/local/bin/python setup.py install --prefix=/mnt/@server/export
```

In either case, the `--prefix` option defines the installation base, and the `--exec-prefix` option defines the platform-specific installation base, which is used for platform-specific files. (Currently, this just means non-pure module distributions, but could be expanded to C libraries, binary executables, etc.) If `--exec-prefix` is not supplied, it defaults to `--prefix`. Files are installed as follows:

Type of file	Installation directory
Python modules	<code>prefix/lib/pythonX.Y/site-packages</code>
extension modules	<code>exec-prefix/lib/pythonX.Y/site-packages</code>
scripts	<code>prefix/bin</code>
data	<code>prefix</code>
C headers	<code>prefix/include/pythonX.Y/distname</code>

There is no requirement that `--prefix` or `--exec-prefix` actually point to an alternate Python installation; if the directories listed above do not already exist, they are created at installation time.

Incidentally, the real reason the prefix scheme is important is simply that a standard Unix installation uses the prefix scheme, but with `--prefix` and `--exec-prefix` supplied by Python itself as `sys.prefix` and `sys.exec_prefix`. Thus, you might think you'll never use the prefix scheme, but every time you run `python setup.py install` without any other options, you're using it.

Note that installing extensions to an alternate Python installation has no effect on how those extensions are built: in particular, the Python header files (`Python.h` and friends) installed with the Python interpreter used to run the setup script will be used in compiling extensions. It is your responsibility to ensure that the interpreter used to run extensions installed in this way is compatible with the interpreter used to build them. The best way to do this is to ensure that the two interpreters are the same version of Python (possibly different builds, or possibly copies of the same build). (Of course, if your `--prefix` and `--exec-prefix` don't even point to an alternate Python installation, this is immaterial.)

### 3.4 Alternate installation: Windows (the prefix scheme)

Windows has no concept of a user's home directory, and since the standard Python installation under Windows is simpler than under Unix, the `--prefix` option has traditionally been used to install additional packages in separate locations on Windows.

```
python setup.py install --prefix="\Temp\Python"
```

to install modules to the `\Temp\Python` directory on the current drive.

The installation base is defined by the `--prefix` option; the `--exec-prefix` option is not supported under Windows, which means that pure Python modules and extension modules are installed into the same location. Files are installed as follows:

Type of file	Installation directory
modules	<code>prefix\Lib\site-packages</code>
scripts	<code>prefix\Scripts</code>
data	<code>prefix</code>
C headers	<code>prefix\Include\distname</code>



# CUSTOM INSTALLATION

Sometimes, the alternate installation schemes described in section *Alternate Installation* just don't do what you want. You might want to tweak just one or two directories while keeping everything under the same base directory, or you might want to completely redefine the installation scheme. In either case, you're creating a *custom installation scheme*.

To create a custom installation scheme, you start with one of the alternate schemes and override some of the installation directories used for the various types of files, using these options:

Type of file	Override option
Python modules	<code>--install-purelib</code>
extension modules	<code>--install-platlib</code>
all modules	<code>--install-lib</code>
scripts	<code>--install-scripts</code>
data	<code>--install-data</code>
C headers	<code>--install-headers</code>

These override options can be relative, absolute, or explicitly defined in terms of one of the installation base directories. (There are two installation base directories, and they are normally the same—they only differ when you use the Unix “prefix scheme” and supply different `--prefix` and `--exec-prefix` options; using `--install-lib` will override values computed or given for `--install-purelib` and `--install-platlib`, and is recommended for schemes that don't make a difference between Python and extension modules.)

For example, say you're installing a module distribution to your home directory under Unix—but you want scripts to go in `~/scripts` rather than `~/bin`. As you might expect, you can override this directory with the `--install-scripts` option; in this case, it makes most sense to supply a relative path, which will be interpreted relative to the installation base directory (your home directory, in this case):

```
python setup.py install --home=~ --install-scripts=scripts
```

Another Unix example: suppose your Python installation was built and installed with a prefix of `/usr/local/python`, so under a standard installation scripts will wind up in `/usr/local/python/bin`. If you want them in `/usr/local/bin` instead, you would supply this absolute directory for the `--install-scripts` option:

```
python setup.py install --install-scripts=/usr/local/bin
```

(This performs an installation using the “prefix scheme,” where the prefix is whatever your Python interpreter was installed with—`/usr/local/python` in this case.)

If you maintain Python on Windows, you might want third-party modules to live in a subdirectory of `prefix`, rather than right in `prefix` itself. This is almost as easy as customizing the script installation directory—you just have to remember that there are two types of modules to worry about, Python and extension modules, which can conveniently be both controlled by one option:

```
python setup.py install --install-lib=Site
```

The specified installation directory is relative to `prefix`. Of course, you also have to ensure that this directory is in Python's module search path, such as by putting a `.pth` file in a site directory (see `site`). See section *Modifying Python's Search Path* to find out how to modify Python's search path.

If you want to define an entire installation scheme, you just have to supply all of the installation directory options. The recommended way to do this is to supply relative paths; for example, if you want to maintain all Python module-related files under `python` in your home directory, and you want a separate directory for each platform that you use your home directory from, you might define the following installation scheme:

```
python setup.py install --home=~ \  
                        --install-purelib=python/lib \  
                        --install-platlib=python/lib.$PLAT \  
                        --install-scripts=python/scripts \  
                        --install-data=python/data
```

or, equivalently,

```
python setup.py install --home=~/python \  
                        --install-purelib=lib \  
                        --install-platlib='lib.$PLAT' \  
                        --install-scripts=scripts \  
                        --install-data=data
```

`$PLAT` is not (necessarily) an environment variable—it will be expanded by the Distutils as it parses your command line options, just as it does when parsing your configuration file(s).

Obviously, specifying the entire installation scheme every time you install a new module distribution would be very tedious. Thus, you can put these options into your Distutils config file (see section *Distutils Configuration Files*):

```
[install]  
install-base=$HOME  
install-purelib=python/lib  
install-platlib=python/lib.$PLAT  
install-scripts=python/scripts  
install-data=python/data
```

or, equivalently,

```
[install]  
install-base=$HOME/python  
install-purelib=lib  
install-platlib=lib.$PLAT  
install-scripts=scripts  
install-data=data
```

Note that these two are *not* equivalent if you supply a different installation base directory when you run the setup script. For example,

```
python setup.py install --install-base=/tmp
```

would install pure modules to `/tmp/python/lib` in the first case, and to `/tmp/lib` in the second case. (For the second case, you probably want to supply an installation base of `/tmp/python`.)

You probably noticed the use of `$HOME` and `$PLAT` in the sample configuration file input. These are Distutils configuration variables, which bear a strong resemblance to environment variables. In fact, you can use environment variables in config files on platforms that have such a notion but the Distutils additionally define a few extra variables that may not be in your environment, such as `$PLAT`. (And of course, on systems that don't have environment variables, such as Mac OS 9, the configuration variables supplied by the Distutils are the only ones you can use.) See section *Distutils Configuration Files* for details.

## 4.1 Modifying Python's Search Path

When the Python interpreter executes an `import` statement, it searches for both Python code and extension modules along a search path. A default value for the path is configured into the Python binary when the interpreter is built. You can determine the path by importing the `sys` module and printing the value of `sys.path`.

```
$ python
Python 2.2 (#11, Oct  3 2002, 13:31:27)
[GCC 2.96 20000731 (Red Hat Linux 7.3 2.96-112)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys.path
['', '/usr/local/lib/python2.3', '/usr/local/lib/python2.3/plat-linux2',
 '/usr/local/lib/python2.3/lib-tk', '/usr/local/lib/python2.3/lib-dynload',
 '/usr/local/lib/python2.3/site-packages']
>>>
```

The null string in `sys.path` represents the current working directory.

The expected convention for locally installed packages is to put them in the `.../site-packages/` directory, but you may want to install Python modules into some arbitrary directory. For example, your site may have a convention of keeping all software related to the web server under `/www`. Add-on Python modules might then belong in `/www/python`, and in order to import them, this directory must be added to `sys.path`. There are several different ways to add the directory.

The most convenient way is to add a path configuration file to a directory that's already on Python's path, usually to the `.../site-packages/` directory. Path configuration files have an extension of `.pth`, and each line must contain a single path that will be appended to `sys.path`. (Because the new paths are appended to `sys.path`, modules in the added directories will not override standard modules. This means you can't use this mechanism for installing fixed versions of standard modules.)

Paths can be absolute or relative, in which case they're relative to the directory containing the `.pth` file. See the documentation of the `site` module for more information.

A slightly less convenient way is to edit the `site.py` file in Python's standard library, and modify `sys.path`. `site.py` is automatically imported when the Python interpreter is executed, unless the `-S` switch is supplied to suppress this behaviour. So you could simply edit `site.py` and add two lines to it:

```
import sys
sys.path.append('/www/python/')
```

However, if you reinstall the same major version of Python (perhaps when upgrading from 2.2 to 2.2.2, for example) `site.py` will be overwritten by the stock version. You'd have to remember that it was modified and save a copy before doing the installation.

There are two environment variables that can modify `sys.path`.

`PYTHONHOME` sets an alternate value for the prefix of the Python installation. For example, if `PYTHONHOME` is set to `/www/python`, the search path will be set to `['', '/www/python/lib/pythonX.Y/', '/www/python/lib/pythonX.Y/plat-linux2', ...]`.

The `PYTHONPATH` variable can be set to a list of paths that will be added to the beginning of `sys.path`. For example, if `PYTHONPATH` is set to `/www/python:/opt/py`, the search path will begin with `['/www/python', '/opt/py']`. (Note that directories must exist in order to be added to `sys.path`; the `site` module removes paths that don't exist.)

Finally, `sys.path` is just a regular Python list, so any Python application can modify it by adding or removing entries.



# DISTUTILS CONFIGURATION FILES

As mentioned above, you can use Distutils configuration files to record personal or site preferences for any Distutils options. That is, any option to any command can be stored in one of two or three (depending on your platform) configuration files, which will be consulted before the command-line is parsed. This means that configuration files will override default values, and the command-line will in turn override configuration files. Furthermore, if multiple configuration files apply, values from “earlier” files are overridden by “later” files.

## 5.1 Location and names of config files

The names and locations of the configuration files vary slightly across platforms. On Unix and Mac OS X, the three configuration files (in the order they are processed) are:

Type of file	Location and filename	Notes
system	prefix/lib/pythonver/distutils/distutils.cfg	(1)
personal	\$HOME/.pydistutils.cfg	(2)
local	setup.cfg	(3)

And on Windows, the configuration files are:

Type of file	Location and filename	Notes
system	prefix\Lib\distutils\distutils.cfg	(4)
personal	%HOME%\pydistutils.cfg	(5)
local	setup.cfg	(3)

On all platforms, the “personal” file can be temporarily disabled by passing the *-no-user-cfg* option.

Notes:

1. Strictly speaking, the system-wide configuration file lives in the directory where the Distutils are installed; under Python 1.6 and later on Unix, this is as shown. For Python 1.5.2, the Distutils will normally be installed to `prefix/lib/python1.5/site-packages/distutils`, so the system configuration file should be put there under Python 1.5.2.
2. On Unix, if the `HOME` environment variable is not defined, the user’s home directory will be determined with the `getpwuid()` function from the standard `pwd` module. This is done by the `os.path.expanduser()` function used by Distutils.
3. I.e., in the current directory (usually the location of the setup script).
4. (See also note (1).) Under Python 1.6 and later, Python’s default “installation prefix” is `C:\Python`, so the system configuration file is normally `C:\Python\Lib\distutils\distutils.cfg`. Under Python 1.5.2, the default prefix was `C:\Program Files\Python`, and the Distutils were not part of the standard library—so the system configuration file would be `C:\Program Files\Python\distutils\distutils.cfg` in a standard Python 1.5.2 installation under Windows.

5. On Windows, if the `HOME` environment variable is not defined,

`USERPROFILE` then `HOMEDRIVE` and `HOMEPATH` will be tried. This is done by the `os.path.expanduser()` function used by Distutils.

## 5.2 Syntax of config files

The Distutils configuration files all have the same syntax. The config files are grouped into sections. There is one section for each Distutils command, plus a `global` section for global options that affect every command. Each section consists of one option per line, specified as `option=value`.

For example, the following is a complete config file that just forces all commands to run quietly by default:

```
[global]
verbose=0
```

If this is installed as the system config file, it will affect all processing of any Python module distribution by any user on the current system. If it is installed as your personal config file (on systems that support them), it will affect only module distributions processed by you. And if it is used as the `setup.cfg` for a particular module distribution, it affects only that distribution.

You could override the default “build base” directory and make the **build\*** commands always forcibly rebuild all files with the following:

```
[build]
build-base=blib
force=1
```

which corresponds to the command-line arguments

```
python setup.py build --build-base=blib --force
```

except that including the **build** command on the command-line means that command will be run. Including a particular command in config files has no such implication; it only means that if the command is run, the options in the config file will apply. (Or if other commands that derive values from it are run, they will use the values in the config file.)

You can find out the complete list of options for any command using the `--help` option, e.g.:

```
python setup.py build --help
```

and you can find out the complete list of global options by using `--help` without a command:

```
python setup.py --help
```

See also the “Reference” section of the “Distributing Python Modules” manual.

# BUILDING EXTENSIONS: TIPS AND TRICKS

Whenever possible, the Distutils try to use the configuration information made available by the Python interpreter used to run the `setup.py` script. For example, the same compiler and linker flags used to compile Python will also be used for compiling extensions. Usually this will work well, but in complicated situations this might be inappropriate. This section discusses how to override the usual Distutils behaviour.

## 6.1 Tweaking compiler/linker flags

Compiling a Python extension written in C or C++ will sometimes require specifying custom flags for the compiler and linker in order to use a particular library or produce a special kind of object code. This is especially true if the extension hasn't been tested on your platform, or if you're trying to cross-compile Python.

In the most general case, the extension author might have foreseen that compiling the extensions would be complicated, and provided a `Setup` file for you to edit. This will likely only be done if the module distribution contains many separate extension modules, or if they often require elaborate sets of compiler flags in order to work.

A `Setup` file, if present, is parsed in order to get a list of extensions to build. Each line in a `Setup` describes a single module. Lines have the following structure:

```
module ... [sourcefile ...] [cpparg ...] [library ...]
```

Let's examine each of the fields in turn.

- *module* is the name of the extension module to be built, and should be a valid Python identifier. You can't just change this in order to rename a module (edits to the source code would also be needed), so this should be left alone.
- *sourcefile* is anything that's likely to be a source code file, at least judging by the filename. Filenames ending in `.c` are assumed to be written in C, filenames ending in `.C`, `.cc`, and `.c++` are assumed to be C++, and filenames ending in `.m` or `.mm` are assumed to be in Objective C.
- *cpparg* is an argument for the C preprocessor, and is anything starting with `-I`, `-D`, `-U` or `-C`.
- *library* is anything ending in `.a` or beginning with `-l` or `-L`.

If a particular platform requires a special library on your platform, you can add it by editing the `Setup` file and running `python setup.py build`. For example, if the module defined by the line

```
foo foomodule.c
```

must be linked with the math library `libm.a` on your platform, simply add `-lm` to the line:

```
foo foomodule.c -lm
```

Arbitrary switches intended for the compiler or the linker can be supplied with the `-Xcompiler arg` and `-Xlinker arg` options:

```
foo foomodule.c -Xcompiler -o32 -Xlinker -shared -lm
```

The next option after `-Xcompiler` and `-Xlinker` will be appended to the proper command line, so in the above example the compiler will be passed the `-o32` option, and the linker will be passed `-shared`. If a compiler option requires an argument, you'll have to supply multiple `-Xcompiler` options; for example, to pass `-x c++` the Setup file would have to contain `-Xcompiler -x -Xcompiler c++`.

Compiler flags can also be supplied through setting the `CFLAGS` environment variable. If set, the contents of `CFLAGS` will be added to the compiler flags specified in the Setup file.

## 6.2 Using non-Microsoft compilers on Windows

### 6.2.1 Borland/CodeGear C++

This subsection describes the necessary steps to use Distutils with the Borland C++ compiler version 5.5. First you have to know that Borland's object file format (OMF) is different from the format used by the Python version you can download from the Python or ActiveState Web site. (Python is built with Microsoft Visual C++, which uses COFF as the object file format.) For this reason you have to convert Python's library `python25.lib` into the Borland format. You can do this as follows:

```
coff2omf python25.lib python25_bcpp.lib
```

The `coff2omf` program comes with the Borland compiler. The file `python25.lib` is in the `Libs` directory of your Python installation. If your extension uses other libraries (`zlib`, ...) you have to convert them too.

The converted files have to reside in the same directories as the normal libraries.

How does Distutils manage to use these libraries with their changed names? If the extension needs a library (eg. `foo`) Distutils checks first if it finds a library with suffix `_bcpp` (eg. `foo_bcpp.lib`) and then uses this library. In the case it doesn't find such a special library it uses the default name (`foo.lib`).<sup>1</sup>

To let Distutils compile your extension with Borland C++ you now have to type:

```
python setup.py build --compiler=bcpp
```

If you want to use the Borland C++ compiler as the default, you could specify this in your personal or system-wide configuration file for Distutils (see section *Distutils Configuration Files*.)

#### See Also:

**C++Builder Compiler** Information about the free C++ compiler from Borland, including links to the download pages.

**Creating Python Extensions Using Borland's Free Compiler** Document describing how to use Borland's free command-line C++ compiler to build Python.

### 6.2.2 GNU C / Cygwin / MinGW

This section describes the necessary steps to use Distutils with the GNU C/C++ compilers in their Cygwin and MinGW distributions.<sup>2</sup> For a Python interpreter that was built with Cygwin, everything should work without any of these following steps.

---

<sup>1</sup> This also means you could replace all existing COFF-libraries with OMF-libraries of the same name.

<sup>2</sup> Check <http://sources.redhat.com/cygwin/> and <http://www.mingw.org/> for more information

Not all extensions can be built with MinGW or Cygwin, but many can. Extensions most likely to not work are those that use C++ or depend on Microsoft Visual C extensions.

To let Distutils compile your extension with Cygwin you have to type:

```
python setup.py build --compiler=cygwin
```

and for Cygwin in no-cygwin mode<sup>3</sup> or for MinGW type:

```
python setup.py build --compiler=mingw32
```

If you want to use any of these options/compiler as default, you should consider writing it in your personal or system-wide configuration file for Distutils (see section *Distutils Configuration Files*.)

### Older Versions of Python and MinGW

The following instructions only apply if you're using a version of Python inferior to 2.4.1 with a MinGW inferior to 3.0.0 (with binutils-2.13.90-20030111-1).

These compilers require some special libraries. This task is more complex than for Borland's C++, because there is no program to convert the library. First you have to create a list of symbols which the Python DLL exports. (You can find a good program for this task at [http://www.emmestech.com/software/pexports-0.43/download\\_pexports.html](http://www.emmestech.com/software/pexports-0.43/download_pexports.html)).

```
pexports python25.dll >python25.def
```

The location of an installed `python25.dll` will depend on the installation options and the version and language of Windows. In a "just for me" installation, it will appear in the root of the installation directory. In a shared installation, it will be located in the system directory.

Then you can create from these information an import library for gcc.

```
/cygwin/bin/dlltool --dllname python25.dll --def python25.def --output-lib libpython25.a
```

The resulting library has to be placed in the same directory as `python25.lib`. (Should be the `libs` directory under your Python installation directory.)

If your extension uses other libraries (zlib,...) you might have to convert them too. The converted files have to reside in the same directories as the normal libraries do.

#### See Also:

**Building Python modules on MS Windows platform with MinGW** Information about building the required libraries for the MinGW environment.

---

<sup>3</sup> Then you have no POSIX emulation available, but you also don't need `cygwin1.dll`.



---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**. . .** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to 2 in contrast to the 2.75 returned by float true division. Note that `(-11) // 4` is -3 because that is -2.75 rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to 2. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to 2.75. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

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# ABOUT THESE DOCUMENTS

These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

Continued on next page

Table C.1 – continued from previous page

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

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**Note:** GPL-compatible doesn't mean that we're distributing Python under the GPL. All Python licenses, unlike the GPL, let you distribute a modified version without making your changes open source. The GPL-compatible licenses make it possible to combine Python with other software that is released under the GPL; the others don't.

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

## C.2 Terms and conditions for accessing or otherwise using Python

### PSF LICENSE AGREEMENT FOR PYTHON 2.7.3

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matsumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

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```

```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matsumoto/emt.html
email: matsumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
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```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
references to Ghostscript; clarified derivation from RFC 1321;
now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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Modified by Jack Jansen, CWI, July 1995:

- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

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```

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Jean-loup Gailly  
jloup@gzip.org

Mark Adler  
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# Python Tutorial

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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Python is an easy to learn, powerful programming language. It has efficient high-level data structures and a simple but effective approach to object-oriented programming. Python's elegant syntax and dynamic typing, together with its interpreted nature, make it an ideal language for scripting and rapid application development in many areas on most platforms.

The Python interpreter and the extensive standard library are freely available in source or binary form for all major platforms from the Python Web site, <http://www.python.org/>, and may be freely distributed. The same site also contains distributions of and pointers to many free third party Python modules, programs and tools, and additional documentation.

The Python interpreter is easily extended with new functions and data types implemented in C or C++ (or other languages callable from C). Python is also suitable as an extension language for customizable applications.

This tutorial introduces the reader informally to the basic concepts and features of the Python language and system. It helps to have a Python interpreter handy for hands-on experience, but all examples are self-contained, so the tutorial can be read off-line as well.

For a description of standard objects and modules, see *library-index*. *reference-index* gives a more formal definition of the language. To write extensions in C or C++, read *extending-index* and *c-api-index*. There are also several books covering Python in depth.

This tutorial does not attempt to be comprehensive and cover every single feature, or even every commonly used feature. Instead, it introduces many of Python's most noteworthy features, and will give you a good idea of the language's flavor and style. After reading it, you will be able to read and write Python modules and programs, and you will be ready to learn more about the various Python library modules described in *library-index*.

The *Glossary* is also worth going through.



# WHETTING YOUR APPETITE

If you do much work on computers, eventually you find that there's some task you'd like to automate. For example, you may wish to perform a search-and-replace over a large number of text files, or rename and rearrange a bunch of photo files in a complicated way. Perhaps you'd like to write a small custom database, or a specialized GUI application, or a simple game.

If you're a professional software developer, you may have to work with several C/C++/Java libraries but find the usual write/compile/test/re-compile cycle is too slow. Perhaps you're writing a test suite for such a library and find writing the testing code a tedious task. Or maybe you've written a program that could use an extension language, and you don't want to design and implement a whole new language for your application.

Python is just the language for you.

You could write a Unix shell script or Windows batch files for some of these tasks, but shell scripts are best at moving around files and changing text data, not well-suited for GUI applications or games. You could write a C/C++/Java program, but it can take a lot of development time to get even a first-draft program. Python is simpler to use, available on Windows, Mac OS X, and Unix operating systems, and will help you get the job done more quickly.

Python is simple to use, but it is a real programming language, offering much more structure and support for large programs than shell scripts or batch files can offer. On the other hand, Python also offers much more error checking than C, and, being a *very-high-level language*, it has high-level data types built in, such as flexible arrays and dictionaries. Because of its more general data types Python is applicable to a much larger problem domain than Awk or even Perl, yet many things are at least as easy in Python as in those languages.

Python allows you to split your program into modules that can be reused in other Python programs. It comes with a large collection of standard modules that you can use as the basis of your programs — or as examples to start learning to program in Python. Some of these modules provide things like file I/O, system calls, sockets, and even interfaces to graphical user interface toolkits like Tk.

Python is an interpreted language, which can save you considerable time during program development because no compilation and linking is necessary. The interpreter can be used interactively, which makes it easy to experiment with features of the language, to write throw-away programs, or to test functions during bottom-up program development. It is also a handy desk calculator.

Python enables programs to be written compactly and readably. Programs written in Python are typically much shorter than equivalent C, C++, or Java programs, for several reasons:

- the high-level data types allow you to express complex operations in a single statement;
- statement grouping is done by indentation instead of beginning and ending brackets;
- no variable or argument declarations are necessary.

Python is *extensible*: if you know how to program in C it is easy to add a new built-in function or module to the interpreter, either to perform critical operations at maximum speed, or to link Python programs to libraries that may only be available in binary form (such as a vendor-specific graphics library). Once you are really hooked, you can

link the Python interpreter into an application written in C and use it as an extension or command language for that application.

By the way, the language is named after the BBC show “Monty Python’s Flying Circus” and has nothing to do with reptiles. Making references to Monty Python skits in documentation is not only allowed, it is encouraged!

Now that you are all excited about Python, you’ll want to examine it in some more detail. Since the best way to learn a language is to use it, the tutorial invites you to play with the Python interpreter as you read.

In the next chapter, the mechanics of using the interpreter are explained. This is rather mundane information, but essential for trying out the examples shown later.

The rest of the tutorial introduces various features of the Python language and system through examples, beginning with simple expressions, statements and data types, through functions and modules, and finally touching upon advanced concepts like exceptions and user-defined classes.

# USING THE PYTHON INTERPRETER

## 2.1 Invoking the Interpreter

The Python interpreter is usually installed as `/usr/local/bin/python` on those machines where it is available; putting `/usr/local/bin` in your Unix shell's search path makes it possible to start it by typing the command

```
python
```

to the shell. Since the choice of the directory where the interpreter lives is an installation option, other places are possible; check with your local Python guru or system administrator. (E.g., `/usr/local/python` is a popular alternative location.)

On Windows machines, the Python installation is usually placed in `C:\Python27`, though you can change this when you're running the installer. To add this directory to your path, you can type the following command into the command prompt in a DOS box:

```
set path=%path%;C:\python27
```

Typing an end-of-file character (`Control-D` on Unix, `Control-Z` on Windows) at the primary prompt causes the interpreter to exit with a zero exit status. If that doesn't work, you can exit the interpreter by typing the following command: `quit()`.

The interpreter's line-editing features usually aren't very sophisticated. On Unix, whoever installed the interpreter may have enabled support for the GNU readline library, which adds more elaborate interactive editing and history features. Perhaps the quickest check to see whether command line editing is supported is typing `Control-P` to the first Python prompt you get. If it beeps, you have command line editing; see Appendix *Interactive Input Editing and History Substitution* for an introduction to the keys. If nothing appears to happen, or if `^P` is echoed, command line editing isn't available; you'll only be able to use backspace to remove characters from the current line.

The interpreter operates somewhat like the Unix shell: when called with standard input connected to a tty device, it reads and executes commands interactively; when called with a file name argument or with a file as standard input, it reads and executes a *script* from that file.

A second way of starting the interpreter is `python -c command [arg] ...`, which executes the statement(s) in *command*, analogous to the shell's `-c` option. Since Python statements often contain spaces or other characters that are special to the shell, it is usually advised to quote *command* in its entirety with single quotes.

Some Python modules are also useful as scripts. These can be invoked using `python -m module [arg] ...`, which executes the source file for *module* as if you had spelled out its full name on the command line.

When a script file is used, it is sometimes useful to be able to run the script and enter interactive mode afterwards. This can be done by passing `-i` before the script.

## 2.1.1 Argument Passing

When known to the interpreter, the script name and additional arguments thereafter are turned into a list of strings and assigned to the `argv` variable in the `sys` module. You can access this list by executing `import sys`. The length of the list is at least one; when no script and no arguments are given, `sys.argv[0]` is an empty string. When the script name is given as `'-'` (meaning standard input), `sys.argv[0]` is set to `'-'`. When `-c command` is used, `sys.argv[0]` is set to `'-c'`. When `-m module` is used, `sys.argv[0]` is set to the full name of the located module. Options found after `-c command` or `-m module` are not consumed by the Python interpreter's option processing but left in `sys.argv` for the command or module to handle.

## 2.1.2 Interactive Mode

When commands are read from a tty, the interpreter is said to be in *interactive mode*. In this mode it prompts for the next command with the *primary prompt*, usually three greater-than signs (`>>>`); for continuation lines it prompts with the *secondary prompt*, by default three dots (`. . .`). The interpreter prints a welcome message stating its version number and a copyright notice before printing the first prompt:

```
python
Python 2.7 (#1, Feb 28 2010, 00:02:06)
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Continuation lines are needed when entering a multi-line construct. As an example, take a look at this `if` statement:

```
>>> the_world_is_flat = 1
>>> if the_world_is_flat:
...     print "Be careful not to fall off!"
...
Be careful not to fall off!
```

## 2.2 The Interpreter and Its Environment

### 2.2.1 Error Handling

When an error occurs, the interpreter prints an error message and a stack trace. In interactive mode, it then returns to the primary prompt; when input came from a file, it exits with a nonzero exit status after printing the stack trace. (Exceptions handled by an `except` clause in a `try` statement are not errors in this context.) Some errors are unconditionally fatal and cause an exit with a nonzero exit; this applies to internal inconsistencies and some cases of running out of memory. All error messages are written to the standard error stream; normal output from executed commands is written to standard output.

Typing the interrupt character (usually Control-C or DEL) to the primary or secondary prompt cancels the input and returns to the primary prompt. <sup>1</sup> Typing an interrupt while a command is executing raises the `KeyboardInterrupt` exception, which may be handled by a `try` statement.

### 2.2.2 Executable Python Scripts

On BSD-ish Unix systems, Python scripts can be made directly executable, like shell scripts, by putting the line

```
#!/usr/bin/env python
```

---

<sup>1</sup> A problem with the GNU Readline package may prevent this.

(assuming that the interpreter is on the user's `PATH`) at the beginning of the script and giving the file an executable mode. The `#!` must be the first two characters of the file. On some platforms, this first line must end with a Unix-style line ending (`'\n'`), not a Windows (`'\r\n'`) line ending. Note that the hash, or pound, character, `'#'`, is used to start a comment in Python.

The script can be given an executable mode, or permission, using the **chmod** command:

```
$ chmod +x myscript.py
```

On Windows systems, there is no notion of an “executable mode”. The Python installer automatically associates `.py` files with `python.exe` so that a double-click on a Python file will run it as a script. The extension can also be `.pyw`, in that case, the console window that normally appears is suppressed.

### 2.2.3 Source Code Encoding

It is possible to use encodings different than ASCII in Python source files. The best way to do it is to put one more special comment line right after the `#!` line to define the source file encoding:

```
# -*- coding: encoding -*-
```

With that declaration, all characters in the source file will be treated as having the encoding *encoding*, and it will be possible to directly write Unicode string literals in the selected encoding. The list of possible encodings can be found in the Python Library Reference, in the section on `codecs`.

For example, to write Unicode literals including the Euro currency symbol, the ISO-8859-15 encoding can be used, with the Euro symbol having the ordinal value 164. This script will print the value 8364 (the Unicode codepoint corresponding to the Euro symbol) and then exit:

```
# -*- coding: iso-8859-15 -*-
```

```
currency = u"€"
print ord(currency)
```

If your editor supports saving files as UTF-8 with a UTF-8 *byte order mark* (aka BOM), you can use that instead of an encoding declaration. IDLE supports this capability if `Options/General/Default Source Encoding/UTF-8` is set. Notice that this signature is not understood in older Python releases (2.2 and earlier), and also not understood by the operating system for script files with `#!` lines (only used on Unix systems).

By using UTF-8 (either through the signature or an encoding declaration), characters of most languages in the world can be used simultaneously in string literals and comments. Using non-ASCII characters in identifiers is not supported. To display all these characters properly, your editor must recognize that the file is UTF-8, and it must use a font that supports all the characters in the file.

### 2.2.4 The Interactive Startup File

When you use Python interactively, it is frequently handy to have some standard commands executed every time the interpreter is started. You can do this by setting an environment variable named `PYTHONSTARTUP` to the name of a file containing your start-up commands. This is similar to the `.profile` feature of the Unix shells.

This file is only read in interactive sessions, not when Python reads commands from a script, and not when `/dev/tty` is given as the explicit source of commands (which otherwise behaves like an interactive session). It is executed in the same namespace where interactive commands are executed, so that objects that it defines or imports can be used without qualification in the interactive session. You can also change the prompts `sys.ps1` and `sys.ps2` in this file.

If you want to read an additional start-up file from the current directory, you can program this in the global start-up file using code like `if os.path.isfile('.pythonrc.py'): execfile('.pythonrc.py')`. If you want to use the startup file in a script, you must do this explicitly in the script:

```
import os
filename = os.environ.get('PYTHONSTARTUP')
if filename and os.path.isfile(filename):
    execfile(filename)
```

## 2.2.5 The Customization Modules

Python provides two hooks to let you customize it: `sitecustomize` and `usercustomize`. To see how it works, you need first to find the location of your user site-packages directory. Start Python and run this code:

```
>>> import site
>>> site.getusersitepackages()
'/home/user/.local/lib/python3.2/site-packages'
```

Now you can create a file named `usercustomize.py` in that directory and put anything you want in it. It will affect every invocation of Python, unless it is started with the `-s` option to disable the automatic import.

`sitecustomize` works in the same way, but is typically created by an administrator of the computer in the global site-packages directory, and is imported before `usercustomize`. See the documentation of the `site` module for more details.

# AN INFORMAL INTRODUCTION TO PYTHON

In the following examples, input and output are distinguished by the presence or absence of prompts (`>>>` and `...`): to repeat the example, you must type everything after the prompt, when the prompt appears; lines that do not begin with a prompt are output from the interpreter. Note that a secondary prompt on a line by itself in an example means you must type a blank line; this is used to end a multi-line command.

Many of the examples in this manual, even those entered at the interactive prompt, include comments. Comments in Python start with the hash character, `#`, and extend to the end of the physical line. A comment may appear at the start of a line or following whitespace or code, but not within a string literal. A hash character within a string literal is just a hash character. Since comments are to clarify code and are not interpreted by Python, they may be omitted when typing in examples.

Some examples:

```
# this is the first comment
SPAM = 1                    # and this is the second comment
                             # ... and now a third!
STRING = "# This is not a comment."
```

## 3.1 Using Python as a Calculator

Let's try some simple Python commands. Start the interpreter and wait for the primary prompt, `>>>`. (It shouldn't take long.)

### 3.1.1 Numbers

The interpreter acts as a simple calculator: you can type an expression at it and it will write the value. Expression syntax is straightforward: the operators `+`, `-`, `*` and `/` work just like in most other languages (for example, Pascal or C); parentheses can be used for grouping. For example:

```
>>> 2+2
4
>>> # This is a comment
... 2+2
4
>>> 2+2 # and a comment on the same line as code
4
>>> (50-5*6)/4
```

```
5
>>> # Integer division returns the floor:
... 7/3
2
>>> 7/-3
-3
```

The equal sign ('=') is used to assign a value to a variable. Afterwards, no result is displayed before the next interactive prompt:

```
>>> width = 20
>>> height = 5*9
>>> width * height
900
```

A value can be assigned to several variables simultaneously:

```
>>> x = y = z = 0 # Zero x, y and z
>>> x
0
>>> y
0
>>> z
0
```

Variables must be “defined” (assigned a value) before they can be used, or an error will occur:

```
>>> # try to access an undefined variable
... n
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'n' is not defined
```

There is full support for floating point; operators with mixed type operands convert the integer operand to floating point:

```
>>> 3 * 3.75 / 1.5
7.5
>>> 7.0 / 2
3.5
```

Complex numbers are also supported; imaginary numbers are written with a suffix of `j` or `J`. Complex numbers with a nonzero real component are written as `(real+imagj)`, or can be created with the `complex(real, imag)` function.

```
>>> 1j * 1J
(-1+0j)
>>> 1j * complex(0,1)
(-1+0j)
>>> 3+1j*3
(3+3j)
>>> (3+1j)*3
(9+3j)
>>> (1+2j)/(1+1j)
(1.5+0.5j)
```

Complex numbers are always represented as two floating point numbers, the real and imaginary part. To extract these parts from a complex number `z`, use `z.real` and `z.imag`.

```
>>> a=1.5+0.5j
>>> a.real
1.5
>>> a.imag
0.5
```

The conversion functions to floating point and integer (`float()`, `int()` and `long()`) don't work for complex numbers — there is no one correct way to convert a complex number to a real number. Use `abs(z)` to get its magnitude (as a float) or `z.real` to get its real part.

```
>>> a=3.0+4.0j
>>> float(a)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: can't convert complex to float; use abs(z)
>>> a.real
3.0
>>> a.imag
4.0
>>> abs(a) # sqrt(a.real**2 + a.imag**2)
5.0
```

In interactive mode, the last printed expression is assigned to the variable `_`. This means that when you are using Python as a desk calculator, it is somewhat easier to continue calculations, for example:

```
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

This variable should be treated as read-only by the user. Don't explicitly assign a value to it — you would create an independent local variable with the same name masking the built-in variable with its magic behavior.

### 3.1.2 Strings

Besides numbers, Python can also manipulate strings, which can be expressed in several ways. They can be enclosed in single quotes or double quotes:

```
>>> 'spam eggs'
'spam eggs'
>>> 'doesn\'t'
"doesn't"
>>> "doesn't"
"doesn't"
>>> '"Yes," he said.'
'"Yes," he said.'
>>> "\"Yes,\" he said."
'"Yes," he said.'
>>> '"Isn\'t," she said.'
'"Isn\'t," she said.'
```

The interpreter prints the result of string operations in the same way as they are typed for input: inside quotes, and with quotes and other funny characters escaped by backslashes, to show the precise value. The string is enclosed

in double quotes if the string contains a single quote and no double quotes, else it's enclosed in single quotes. The `print` statement produces a more readable output for such input strings.

String literals can span multiple lines in several ways. Continuation lines can be used, with a backslash as the last character on the line indicating that the next line is a logical continuation of the line:

```
hello = "This is a rather long string containing\n\
several lines of text just as you would do in C.\n\
    Note that whitespace at the beginning of the line is\
significant."
```

```
print hello
```

Note that newlines still need to be embedded in the string using `\n` – the newline following the trailing backslash is discarded. This example would print the following:

```
This is a rather long string containing
several lines of text just as you would do in C.
    Note that whitespace at the beginning of the line is significant.
```

Or, strings can be surrounded in a pair of matching triple-quotes: `"""` or `'''`. End of lines do not need to be escaped when using triple-quotes, but they will be included in the string.

```
print """
Usage: thingy [OPTIONS]
    -h                Display this usage message
    -H hostname       Hostname to connect to
"""
```

produces the following output:

```
Usage: thingy [OPTIONS]
    -h                Display this usage message
    -H hostname       Hostname to connect to
```

If we make the string literal a “raw” string, `\n` sequences are not converted to newlines, but the backslash at the end of the line, and the newline character in the source, are both included in the string as data. Thus, the example:

```
hello = r"This is a rather long string containing\n\
several lines of text much as you would do in C."
```

```
print hello
```

would print:

```
This is a rather long string containing\n\
several lines of text much as you would do in C.
```

Strings can be concatenated (glued together) with the `+` operator, and repeated with `*`:

```
>>> word = 'Help' + 'A'
>>> word
'HelpA'
>>> '<' + word*5 + '>'
'<HelpAHelpAHelpAHelpAHelpA>'
```

Two string literals next to each other are automatically concatenated; the first line above could also have been written `word = 'Help' 'A'`; this only works with two literals, not with arbitrary string expressions:

```
>>> 'str' 'ing'                # <- This is ok
'string'
>>> 'str'.strip() + 'ing'      # <- This is ok
```

```
'string'
>>> 'str'.strip() 'ing'      # <- This is invalid
File "<stdin>", line 1, in ?
    'str'.strip() 'ing'
                        ^
```

SyntaxError: invalid syntax

Strings can be subscripted (indexed); like in C, the first character of a string has subscript (index) 0. There is no separate character type; a character is simply a string of size one. Like in Icon, substrings can be specified with the *slice notation*: two indices separated by a colon.

```
>>> word[4]
'A'
>>> word[0:2]
'He'
>>> word[2:4]
'lp'
```

Slice indices have useful defaults; an omitted first index defaults to zero, an omitted second index defaults to the size of the string being sliced.

```
>>> word[:2]      # The first two characters
'He'
>>> word[2:]     # Everything except the first two characters
'lpA'
```

Unlike a C string, Python strings cannot be changed. Assigning to an indexed position in the string results in an error:

```
>>> word[0] = 'x'
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: object does not support item assignment
>>> word[:1] = 'Splat'
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: object does not support slice assignment
```

However, creating a new string with the combined content is easy and efficient:

```
>>> 'x' + word[1:]
'xelpA'
>>> 'Splat' + word[4]
'SplatA'
```

Here's a useful invariant of slice operations: `s[:i] + s[i:]` equals `s`.

```
>>> word[:2] + word[2:]
'HelpA'
>>> word[:3] + word[3:]
'HelpA'
```

Degenerate slice indices are handled gracefully: an index that is too large is replaced by the string size, an upper bound smaller than the lower bound returns an empty string.

```
>>> word[1:100]
'elpA'
>>> word[10:]
''
>>> word[2:1]
''
```

Indices may be negative numbers, to start counting from the right. For example:

```
>>> word[-1]      # The last character
'A'
>>> word[-2]      # The last-but-one character
'p'
>>> word[-2:]     # The last two characters
'pA'
>>> word[:-2]     # Everything except the last two characters
'Hel'
```

But note that `-0` is really the same as `0`, so it does not count from the right!

```
>>> word[-0]      # (since -0 equals 0)
'H'
```

Out-of-range negative slice indices are truncated, but don't try this for single-element (non-slice) indices:

```
>>> word[-100:]
'HelpA'
>>> word[-10]     # error
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
IndexError: string index out of range
```

One way to remember how slices work is to think of the indices as pointing *between* characters, with the left edge of the first character numbered 0. Then the right edge of the last character of a string of  $n$  characters has index  $n$ , for example:

```
+---+---+---+---+---+
| H | e | l | p | A |
+---+---+---+---+
0  1  2  3  4  5
-5 -4 -3 -2 -1
```

The first row of numbers gives the position of the indices 0...5 in the string; the second row gives the corresponding negative indices. The slice from  $i$  to  $j$  consists of all characters between the edges labeled  $i$  and  $j$ , respectively.

For non-negative indices, the length of a slice is the difference of the indices, if both are within bounds. For example, the length of `word[1:3]` is 2.

The built-in function `len()` returns the length of a string:

```
>>> s = 'supercalifragilisticexpialidocious'
>>> len(s)
34
```

#### See Also:

***typeseq*** Strings, and the Unicode strings described in the next section, are examples of *sequence types*, and support the common operations supported by such types.

***string-methods*** Both strings and Unicode strings support a large number of methods for basic transformations and searching.

***new-string-formatting*** Information about string formatting with `str.format()` is described here.

***string-formatting*** The old formatting operations invoked when strings and Unicode strings are the left operand of the `%` operator are described in more detail here.

### 3.1.3 Unicode Strings

Starting with Python 2.0 a new data type for storing text data is available to the programmer: the Unicode object. It can be used to store and manipulate Unicode data (see <http://www.unicode.org/>) and integrates well with the existing string objects, providing auto-conversions where necessary.

Unicode has the advantage of providing one ordinal for every character in every script used in modern and ancient texts. Previously, there were only 256 possible ordinals for script characters. Texts were typically bound to a code page which mapped the ordinals to script characters. This led to very much confusion especially with respect to internationalization (usually written as *i18n* — 'i' + 18 characters + 'n') of software. Unicode solves these problems by defining one code page for all scripts.

Creating Unicode strings in Python is just as simple as creating normal strings:

```
>>> u'Hello World !'
u'Hello World !'
```

The small 'u' in front of the quote indicates that a Unicode string is supposed to be created. If you want to include special characters in the string, you can do so by using the Python *Unicode-Escape* encoding. The following example shows how:

```
>>> u'Hello\u0020World !'
u'Hello World !'
```

The escape sequence `\u0020` indicates to insert the Unicode character with the ordinal value 0x0020 (the space character) at the given position.

Other characters are interpreted by using their respective ordinal values directly as Unicode ordinals. If you have literal strings in the standard Latin-1 encoding that is used in many Western countries, you will find it convenient that the lower 256 characters of Unicode are the same as the 256 characters of Latin-1.

For experts, there is also a raw mode just like the one for normal strings. You have to prefix the opening quote with 'ur' to have Python use the *Raw-Unicode-Escape* encoding. It will only apply the above `\uXXXX` conversion if there is an uneven number of backslashes in front of the small 'u'.

```
>>> ur'Hello\u0020World !'
u'Hello World !'
>>> ur'Hello\\u0020World !'
u'Hello\\\u0020World !'
```

The raw mode is most useful when you have to enter lots of backslashes, as can be necessary in regular expressions.

Apart from these standard encodings, Python provides a whole set of other ways of creating Unicode strings on the basis of a known encoding.

The built-in function `unicode()` provides access to all registered Unicode codecs (COders and DECOders). Some of the more well known encodings which these codecs can convert are *Latin-1*, *ASCII*, *UTF-8*, and *UTF-16*. The latter two are variable-length encodings that store each Unicode character in one or more bytes. The default encoding is normally set to *ASCII*, which passes through characters in the range 0 to 127 and rejects any other characters with an error. When a Unicode string is printed, written to a file, or converted with `str()`, conversion takes place using this default encoding.

```
>>> u"abc"
u' abc'
>>> str(u"abc")
' abc'
>>> u"äöü"
u' \xe4\xfc'
>>> str(u"äöü")
Traceback (most recent call last):
```

```
File "<stdin>", line 1, in ?
UnicodeEncodeError: 'ascii' codec can't encode characters in position 0-2: ordinal not in
```

To convert a Unicode string into an 8-bit string using a specific encoding, Unicode objects provide an `encode()` method that takes one argument, the name of the encoding. Lowercase names for encodings are preferred.

```
>>> u"äöü".encode('utf-8')
'\xc3\xa4\xc3\xb6\xc3\xbc'
```

If you have data in a specific encoding and want to produce a corresponding Unicode string from it, you can use the `unicode()` function with the encoding name as the second argument.

```
>>> unicode('\xc3\xa4\xc3\xb6\xc3\xbc', 'utf-8')
u'\xe4\xf6\xfc'
```

### 3.1.4 Lists

Python knows a number of *compound* data types, used to group together other values. The most versatile is the *list*, which can be written as a list of comma-separated values (items) between square brackets. List items need not all have the same type.

```
>>> a = ['spam', 'eggs', 100, 1234]
>>> a
['spam', 'eggs', 100, 1234]
```

Like string indices, list indices start at 0, and lists can be sliced, concatenated and so on:

```
>>> a[0]
'spam'
>>> a[3]
1234
>>> a[-2]
100
>>> a[1:-1]
['eggs', 100]
>>> a[:2] + ['bacon', 2*2]
['spam', 'eggs', 'bacon', 4]
>>> 3*a[:3] + ['Boo!']
['spam', 'eggs', 100, 'spam', 'eggs', 100, 'spam', 'eggs', 100, 'Boo!']
```

All slice operations return a new list containing the requested elements. This means that the following slice returns a shallow copy of the list `a`:

```
>>> a[:]
['spam', 'eggs', 100, 1234]
```

Unlike strings, which are *immutable*, it is possible to change individual elements of a list:

```
>>> a
['spam', 'eggs', 100, 1234]
>>> a[2] = a[2] + 23
>>> a
['spam', 'eggs', 123, 1234]
```

Assignment to slices is also possible, and this can even change the size of the list or clear it entirely:

```
>>> # Replace some items:
... a[0:2] = [1, 12]
>>> a
[1, 12, 123, 1234]
```

```

>>> # Remove some:
... a[0:2] = []
>>> a
[123, 1234]
>>> # Insert some:
... a[1:1] = ['bletch', 'xyzyz']
>>> a
[123, 'bletch', 'xyzyz', 1234]
>>> # Insert (a copy of) itself at the beginning
>>> a[:0] = a
>>> a
[123, 'bletch', 'xyzyz', 1234, 123, 'bletch', 'xyzyz', 1234]
>>> # Clear the list: replace all items with an empty list
>>> a[:] = []
>>> a
[]

```

The built-in function `len()` also applies to lists:

```

>>> a = ['a', 'b', 'c', 'd']
>>> len(a)
4

```

It is possible to nest lists (create lists containing other lists), for example:

```

>>> q = [2, 3]
>>> p = [1, q, 4]
>>> len(p)
3
>>> p[1]
[2, 3]
>>> p[1][0]
2
>>> p[1].append('extra')      # See section 5.1
>>> p
[1, [2, 3, 'extra'], 4]
>>> q
[2, 3, 'extra']

```

Note that in the last example, `p[1]` and `q` really refer to the same object! We'll come back to *object semantics* later.

## 3.2 First Steps Towards Programming

Of course, we can use Python for more complicated tasks than adding two and two together. For instance, we can write an initial sub-sequence of the *Fibonacci* series as follows:

```

>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while b < 10:
...     print b
...     a, b = b, a+b
...
1
1

```

2  
3  
5  
8

This example introduces several new features.

- The first line contains a *multiple assignment*: the variables `a` and `b` simultaneously get the new values 0 and 1. On the last line this is used again, demonstrating that the expressions on the right-hand side are all evaluated first before any of the assignments take place. The right-hand side expressions are evaluated from the left to the right.
- The `while` loop executes as long as the condition (here: `b < 10`) remains true. In Python, like in C, any non-zero integer value is true; zero is false. The condition may also be a string or list value, in fact any sequence; anything with a non-zero length is true, empty sequences are false. The test used in the example is a simple comparison. The standard comparison operators are written the same as in C: `<` (less than), `>` (greater than), `==` (equal to), `<=` (less than or equal to), `>=` (greater than or equal to) and `!=` (not equal to).
- The *body* of the loop is *indented*: indentation is Python's way of grouping statements. At the interactive prompt, you have to type a tab or space(s) for each indented line. In practice you will prepare more complicated input for Python with a text editor; all decent text editors have an auto-indent facility. When a compound statement is entered interactively, it must be followed by a blank line to indicate completion (since the parser cannot guess when you have typed the last line). Note that each line within a basic block must be indented by the same amount.
- The `print` statement writes the value of the expression(s) it is given. It differs from just writing the expression you want to write (as we did earlier in the calculator examples) in the way it handles multiple expressions and strings. Strings are printed without quotes, and a space is inserted between items, so you can format things nicely, like this:

```
>>> i = 256*256
>>> print 'The value of i is', i
The value of i is 65536
```

A trailing comma avoids the newline after the output:

```
>>> a, b = 0, 1
>>> while b < 1000:
...     print b,
...     a, b = b, a+b
...
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
```

Note that the interpreter inserts a newline before it prints the next prompt if the last line was not completed.

# MORE CONTROL FLOW TOOLS

Besides the `while` statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1 `if` Statements

Perhaps the most well-known statement type is the `if` statement. For example:

```
>>> x = int(raw_input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print 'Negative changed to zero'
... elif x == 0:
...     print 'Zero'
... elif x == 1:
...     print 'Single'
... else:
...     print 'More'
...
More
```

There can be zero or more `elif` parts, and the `else` part is optional. The keyword ‘`elif`’ is short for ‘else if’, and is useful to avoid excessive indentation. An `if ... elif ... elif ...` sequence is a substitute for the `switch` or `case` statements found in other languages.

## 4.2 `for` Statements

The `for` statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s `for` statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

```
>>> # Measure some strings:
... a = ['cat', 'window', 'defenestrate']
>>> for x in a:
...     print x, len(x)
...
cat 3
```

```
window 6
defenestrate 12
```

It is not safe to modify the sequence being iterated over in the loop (this can only happen for mutable sequence types, such as lists). If you need to modify the list you are iterating over (for example, to duplicate selected items) you must iterate over a copy. The slice notation makes this particularly convenient:

```
>>> for x in a[:]: # make a slice copy of the entire list
...     if len(x) > 6: a.insert(0, x)
...
>>> a
['defenestrate', 'cat', 'window', 'defenestrate']
```

### 4.3 The range () Function

If you do need to iterate over a sequence of numbers, the built-in function `range ()` comes in handy. It generates lists containing arithmetic progressions:

```
>>> range(10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

The given end point is never part of the generated list; `range(10)` generates a list of 10 values, the legal indices for items of a sequence of length 10. It is possible to let the range start at another number, or to specify a different increment (even negative; sometimes this is called the ‘step’):

```
>>> range(5, 10)
[5, 6, 7, 8, 9]
>>> range(0, 10, 3)
[0, 3, 6, 9]
>>> range(-10, -100, -30)
[-10, -40, -70]
```

To iterate over the indices of a sequence, you can combine `range ()` and `len ()` as follows:

```
>>> a = ['Mary', 'had', 'a', 'little', 'lamb']
>>> for i in range(len(a)):
...     print i, a[i]
...
0 Mary
1 had
2 a
3 little
4 lamb
```

In most such cases, however, it is convenient to use the `enumerate ()` function, see *Looping Techniques*.

### 4.4 break and continue Statements, and else Clauses on Loops

The `break` statement, like in C, breaks out of the smallest enclosing `for` or `while` loop.

Loop statements may have an `else` clause; it is executed when the loop terminates through exhaustion of the list (with `for`) or when the condition becomes false (with `while`), but not when the loop is terminated by a `break` statement. This is exemplified by the following loop, which searches for prime numbers:

```
>>> for n in range(2, 10):
...     for x in range(2, n):
```

```

...         if n % x == 0:
...             print n, 'equals', x, '*', n/x
...             break
...         else:
...             # loop fell through without finding a factor
...             print n, 'is a prime number'
...
2 is a prime number
3 is a prime number
4 equals 2 * 2
5 is a prime number
6 equals 2 * 3
7 is a prime number
8 equals 2 * 4
9 equals 3 * 3

```

(Yes, this is the correct code. Look closely: the `else` clause belongs to the `for` loop, **not** the `if` statement.)

When used with a loop, the `else` clause has more in common with the `else` clause of a `try` statement than it does that of `if` statements: a `try` statement's `else` clause runs when no exception occurs, and a loop's `else` clause runs when no `break` occurs. For more on the `try` statement and exceptions, see *Handling Exceptions*.

The `continue` statement, also borrowed from C, continues with the next iteration of the loop:

```

>>> for num in range(2, 10):
...     if num % 2 == 0:
...         print("Found an even number", num)
...         continue
...     print("Found a number", num)
Found an even number 2
Found a number 3
Found an even number 4
Found a number 5
Found an even number 6
Found a number 7
Found an even number 8
Found a number 9

```

## 4.5 pass Statements

The `pass` statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

```

>>> while True:
...     pass # Busy-wait for keyboard interrupt (Ctrl+C)
...

```

This is commonly used for creating minimal classes:

```

>>> class MyEmptyClass:
...     pass
...

```

Another place `pass` can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The `pass` is silently ignored:

```
>>> def initlog(*args):
...     pass # Remember to implement this!
... 
```

## 4.6 Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

```
>>> def fib(n): # write Fibonacci series up to n
...     """Print a Fibonacci series up to n."""
...     a, b = 0, 1
...     while a < n:
...         print a,
...         a, b = b, a+b
...
>>> # Now call the function we just defined:
... fib(2000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597
```

The keyword `def` introduces a function *definition*. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function's documentation string, or *docstring*. (More about docstrings can be found in the section *Documentation Strings*.) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it's good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a `global` statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object).<sup>1</sup> When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

Coming from other languages, you might object that `fib` is not a function but a procedure since it doesn't return a value. In fact, even functions without a `return` statement do return a value, albeit a rather boring one. This value is called `None` (it's a built-in name). Writing the value `None` is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using `print`:

```
>>> fib(0)
>>> print fib(0)
None
```

---

<sup>1</sup> Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list).

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

```
>>> def fib2(n): # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a)    # see below
...         a, b = b, a+b
...     return result
...
>>> f100 = fib2(100)    # call it
>>> f100                # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

This example, as usual, demonstrates some new Python features:

- The `return` statement returns with a value from a function. `return` without an expression argument returns `None`. Falling off the end of a function also returns `None`.
- The statement `result.append(a)` calls a *method* of the list object `result`. A method is a function that ‘belongs’ to an object and is named `obj.methodname`, where `obj` is some object (this may be an expression), and `methodname` is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using *classes*, see *Classes*) The method `append()` shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent to `result = result + [a]`, but more efficient.

## 4.7 More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1 Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

```
def ask_ok(prompt, retries=4, complaint='Yes or no, please!'):
    while True:
        ok = raw_input(prompt)
        if ok in ('y', 'ye', 'yes'):
            return True
        if ok in ('n', 'no', 'nop', 'nope'):
            return False
        retries = retries - 1
        if retries < 0:
            raise IOError('refusenik user')
        print complaint
```

This function can be called in several ways:

- giving only the mandatory argument: `ask_ok('Do you really want to quit?')`
- giving one of the optional arguments: `ask_ok('OK to overwrite the file?', 2)`

- or even giving all arguments: `ask_ok('OK to overwrite the file?', 2, 'Come on, only yes or no!')`

This example also introduces the `in` keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

```
i = 5

def f(arg=i):
    print arg
```

```
i = 6
f()
```

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

```
def f(a, L=[]):
    L.append(a)
    return L
```

```
print f(1)
print f(2)
print f(3)
```

This will print

```
[1]
[1, 2]
[1, 2, 3]
```

If you don't want the default to be shared between subsequent calls, you can write the function like this instead:

```
def f(a, L=None):
    if L is None:
        L = []
    L.append(a)
    return L
```

### 4.7.2 Keyword Arguments

Functions can also be called using *keyword arguments* of the form `kwarg=value`. For instance, the following function:

```
def parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):
    print "-- This parrot wouldn't", action,
    print "if you put", voltage, "volts through it."
    print "-- Lovely plumage, the", type
    print "-- It's", state, "!"
```

accepts one required argument (`voltage`) and three optional arguments (`state`, `action`, and `type`). This function can be called in any of the following ways:

```
parrot(1000) # 1 positional argument
parrot(voltage=1000) # 1 keyword argument
parrot(voltage=1000000, action='VOOOOOM') # 2 keyword arguments
```

```

parrot(action='VOOOOOM', voltage=1000000)           # 2 keyword arguments
parrot('a million', 'bereft of life', 'jump')     # 3 positional arguments
parrot('a thousand', state='pushing up the daisies') # 1 positional, 1 keyword

```

but all the following calls would be invalid:

```

parrot()           # required argument missing
parrot(voltage=5.0, 'dead') # non-keyword argument after a keyword argument
parrot(110, voltage=220)   # duplicate value for the same argument
parrot(actor='John Cleese') # unknown keyword argument

```

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here's an example that fails due to this restriction:

```

>>> def function(a):
...     pass
...
>>> function(0, a=0)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: function() got multiple values for keyword argument 'a'

```

When a final formal parameter of the form `**name` is present, it receives a dictionary (see *typesmapping*) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form `*name` (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (`*name` must occur before `**name`.) For example, if we define a function like this:

```

def cheeseshop(kind, *arguments, **keywords):
    print "-- Do you have any", kind, "?"
    print "-- I'm sorry, we're all out of", kind
    for arg in arguments:
        print arg
    print "-" * 40
    keys = sorted(keywords.keys())
    for kw in keys:
        print kw, ":", keywords[kw]

```

It could be called like this:

```

cheeseshop("Limburger", "It's very runny, sir.",
           "It's really very, VERY runny, sir.",
           shopkeeper='Michael Palin',
           client="John Cleese",
           sketch="Cheese Shop Sketch")

```

and of course it would print:

```

-- Do you have any Limburger ?
-- I'm sorry, we're all out of Limburger
It's very runny, sir.
It's really very, VERY runny, sir.
-----
client : John Cleese
shopkeeper : Michael Palin
sketch : Cheese Shop Sketch

```

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary's `keys()` method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3 Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see *Tuples and Sequences*). Before the variable number of arguments, zero or more normal arguments may occur.

```
def write_multiple_items(file, separator, *args):
    file.write(separator.join(args))
```

### 4.7.4 Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in `range()` function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the `*`-operator to unpack the arguments out of a list or tuple:

```
>>> range(3, 6)                # normal call with separate arguments
[3, 4, 5]
>>> args = [3, 6]
>>> range(*args)               # call with arguments unpacked from a list
[3, 4, 5]
```

In the same fashion, dictionaries can deliver keyword arguments with the `**`-operator:

```
>>> def parrot(voltage, state='a stiff', action='vroom'):
...     print "-- This parrot wouldn't", action,
...     print "if you put", voltage, "volts through it.",
...     print "E's", state, "!"
...
>>> d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}
>>> parrot(**d)
-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised
```

### 4.7.5 Lambda Forms

By popular demand, a few features commonly found in functional programming languages like Lisp have been added to Python. With the `lambda` keyword, small anonymous functions can be created. Here's a function that returns the sum of its two arguments: `lambda a, b: a+b`. Lambda forms can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda forms can reference variables from the containing scope:

```
>>> def make_incrementor(n):
...     return lambda x: x + n
...
>>> f = make_incrementor(42)
>>> f(0)
42
>>> f(1)
43
```

## 4.7.6 Documentation Strings

There are emerging conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object's purpose. For brevity, it should not explicitly state the object's name or type, since these are available by other means (except if the name happens to be a verb describing a function's operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object's calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can't use the first line since it is generally adjacent to the string's opening quotes so its indentation is not apparent in the string literal.) Whitespace "equivalent" to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

```
>>> def my_function():
...     """Do nothing, but document it.
...
...     No, really, it doesn't do anything.
...     """
...     pass
>>> print my_function.__doc__
Do nothing, but document it.

    No, really, it doesn't do anything.
```

## 4.8 Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about *coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, **PEP 8** has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

- Use 4-space indentation, and no tabs.
  - 4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.
- Wrap lines so that they don't exceed 79 characters.
  - This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.
- Use blank lines to separate functions and classes, and larger blocks of code inside functions.
- When possible, put comments on a line of their own.

- Use docstrings.
- Use spaces around operators and after commas, but not directly inside bracketing constructs: `a = f(1, 2) + g(3, 4)`.
- Name your classes and functions consistently; the convention is to use `CamelCase` for classes and `lower_case_with_underscores` for functions and methods. Always use `self` as the name for the first method argument (see *A First Look at Classes* for more on classes and methods).
- Don't use fancy encodings if your code is meant to be used in international environments. Plain ASCII works best in any case.

# DATA STRUCTURES

This chapter describes some things you've learned about already in more detail, and adds some new things as well.

## 5.1 More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

`list.append(x)`

Add an item to the end of the list; equivalent to `a[len(a) :] = [x]`.

`list.extend(L)`

Extend the list by appending all the items in the given list; equivalent to `a[len(a) :] = L`.

`list.insert(i, x)`

Insert an item at a given position. The first argument is the index of the element before which to insert, so `a.insert(0, x)` inserts at the front of the list, and `a.insert(len(a), x)` is equivalent to `a.append(x)`.

`list.remove(x)`

Remove the first item from the list whose value is `x`. It is an error if there is no such item.

`list.pop([i])`

Remove the item at the given position in the list, and return it. If no index is specified, `a.pop()` removes and returns the last item in the list. (The square brackets around the `i` in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

`list.index(x)`

Return the index in the list of the first item whose value is `x`. It is an error if there is no such item.

`list.count(x)`

Return the number of times `x` appears in the list.

`list.sort()`

Sort the items of the list, in place.

`list.reverse()`

Reverse the elements of the list, in place.

An example that uses most of the list methods:

```
>>> a = [66.25, 333, 333, 1, 1234.5]
>>> print a.count(333), a.count(66.25), a.count('x')
2 1 0
>>> a.insert(2, -1)
```

```
>>> a.append(333)
>>> a
[66.25, 333, -1, 333, 1, 1234.5, 333]
>>> a.index(333)
1
>>> a.remove(333)
>>> a
[66.25, -1, 333, 1, 1234.5, 333]
>>> a.reverse()
>>> a
[333, 1234.5, 1, 333, -1, 66.25]
>>> a.sort()
>>> a
[-1, 1, 66.25, 333, 333, 1234.5]
```

### 5.1.1 Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use `append()`. To retrieve an item from the top of the stack, use `pop()` without an explicit index. For example:

```
>>> stack = [3, 4, 5]
>>> stack.append(6)
>>> stack.append(7)
>>> stack
[3, 4, 5, 6, 7]
>>> stack.pop()
7
>>> stack
[3, 4, 5, 6]
>>> stack.pop()
6
>>> stack.pop()
5
>>> stack
[3, 4]
```

### 5.1.2 Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use `collections.deque` which was designed to have fast appends and pops from both ends. For example:

```
>>> from collections import deque
>>> queue = deque(["Eric", "John", "Michael"])
>>> queue.append("Terry")           # Terry arrives
>>> queue.append("Graham")        # Graham arrives
>>> queue.popleft()                # The first to arrive now leaves
'Eric'
>>> queue.popleft()                # The second to arrive now leaves
'John'
```

```
>>> queue                                     # Remaining queue in order of arrival
deque(['Michael', 'Terry', 'Graham'])
```

### 5.1.3 Functional Programming Tools

There are three built-in functions that are very useful when used with lists: `filter()`, `map()`, and `reduce()`.

`filter(function, sequence)` returns a sequence consisting of those items from the sequence for which `function(item)` is true. If *sequence* is a string or tuple, the result will be of the same type; otherwise, it is always a list. For example, to compute a sequence of numbers not divisible by 2 and 3:

```
>>> def f(x): return x % 2 != 0 and x % 3 != 0
...
>>> filter(f, range(2, 25))
[5, 7, 11, 13, 17, 19, 23]
```

`map(function, sequence)` calls `function(item)` for each of the sequence's items and returns a list of the return values. For example, to compute some cubes:

```
>>> def cube(x): return x*x*x
...
>>> map(cube, range(1, 11))
[1, 8, 27, 64, 125, 216, 343, 512, 729, 1000]
```

More than one sequence may be passed; the function must then have as many arguments as there are sequences and is called with the corresponding item from each sequence (or `None` if some sequence is shorter than another). For example:

```
>>> seq = range(8)
>>> def add(x, y): return x+y
...
>>> map(add, seq, seq)
[0, 2, 4, 6, 8, 10, 12, 14]
```

`reduce(function, sequence)` returns a single value constructed by calling the binary function *function* on the first two items of the sequence, then on the result and the next item, and so on. For example, to compute the sum of the numbers 1 through 10:

```
>>> def add(x, y): return x+y
...
>>> reduce(add, range(1, 11))
55
```

If there's only one item in the sequence, its value is returned; if the sequence is empty, an exception is raised.

A third argument can be passed to indicate the starting value. In this case the starting value is returned for an empty sequence, and the function is first applied to the starting value and the first sequence item, then to the result and the next item, and so on. For example,

```
>>> def sum(seq):
...     def add(x, y): return x+y
...     return reduce(add, seq, 0)
...
>>> sum(range(1, 11))
55
>>> sum([])
0
```

Don't use this example's definition of `sum()`: since summing numbers is such a common need, a built-in function `sum(sequence)` is already provided, and works exactly like this. New in version 2.3.

## 5.1.4 List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

```
>>> squares = []
>>> for x in range(10):
...     squares.append(x**2)
...
>>> squares
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

We can obtain the same result with:

```
squares = [x**2 for x in range(10)]
```

This is also equivalent to `squares = map(lambda x: x**2, range(10))`, but it's more concise and readable.

A list comprehension consists of brackets containing an expression followed by a `for` clause, then zero or more `for` or `if` clauses. The result will be a new list resulting from evaluating the expression in the context of the `for` and `if` clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

```
>>> [(x, y) for x in [1,2,3] for y in [3,1,4] if x != y]
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

and it's equivalent to:

```
>>> combs = []
>>> for x in [1,2,3]:
...     for y in [3,1,4]:
...         if x != y:
...             combs.append((x, y))
...
>>> combs
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

Note how the order of the `for` and `if` statements is the same in both these snippets.

If the expression is a tuple (e.g. the `(x, y)` in the previous example), it must be parenthesized.

```
>>> vec = [-4, -2, 0, 2, 4]
>>> # create a new list with the values doubled
>>> [x*2 for x in vec]
[-8, -4, 0, 4, 8]
>>> # filter the list to exclude negative numbers
>>> [x for x in vec if x >= 0]
[0, 2, 4]
>>> # apply a function to all the elements
>>> [abs(x) for x in vec]
[4, 2, 0, 2, 4]
>>> # call a method on each element
>>> freshfruit = [' banana', ' loganberry ', 'passion fruit ']
```

```

>>> [weapon.strip() for weapon in freshfruit]
['banana', 'loganberry', 'passion fruit']
>>> # create a list of 2-tuples like (number, square)
>>> [(x, x**2) for x in range(6)]
[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]
>>> # the tuple must be parenthesized, otherwise an error is raised
>>> [x, x**2 for x in range(6)]
File "<stdin>", line 1
    [x, x**2 for x in range(6)]
        ^

```

**SyntaxError:** invalid syntax

```

>>> # flatten a list using a listcomp with two 'for'
>>> vec = [[1,2,3], [4,5,6], [7,8,9]]
>>> [num for elem in vec for num in elem]
[1, 2, 3, 4, 5, 6, 7, 8, 9]

```

List comprehensions can contain complex expressions and nested functions:

```

>>> from math import pi
>>> [str(round(pi, i)) for i in range(1, 6)]
['3.1', '3.14', '3.142', '3.1416', '3.14159']

```

## Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

```

>>> matrix = [
...     [1, 2, 3, 4],
...     [5, 6, 7, 8],
...     [9, 10, 11, 12],
... ]

```

The following list comprehension will transpose rows and columns:

```

>>> [[row[i] for row in matrix] for i in range(4)]
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

```

As we saw in the previous section, the nested listcomp is evaluated in the context of the `for` that follows it, so this example is equivalent to:

```

>>> transposed = []
>>> for i in range(4):
...     transposed.append([row[i] for row in matrix])
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

```

which, in turn, is the same as:

```

>>> transposed = []
>>> for i in range(4):
...     # the following 3 lines implement the nested listcomp
...     transposed_row = []
...     for row in matrix:
...         transposed_row.append(row[i])
...     transposed.append(transposed_row)

```

```
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

In the real world, you should prefer built-in functions to complex flow statements. The `zip()` function would do a great job for this use case:

```
>>> zip(*matrix)
[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]
```

See *Unpacking Argument Lists* for details on the asterisk in this line.

## 5.2 The `del` statement

There is a way to remove an item from a list given its index instead of its value: the `del` statement. This differs from the `pop()` method which returns a value. The `del` statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

```
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
>>> a
[]
```

`del` can also be used to delete entire variables:

```
>>> del a
```

Referencing the name `a` hereafter is an error (at least until another value is assigned to it). We'll find other uses for `del` later.

## 5.3 Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of *sequence* data types (see *typeseq*). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the *tuple*.

A tuple consists of a number of values separated by commas, for instance:

```
>>> t = 12345, 54321, 'hello!'
>>> t[0]
12345
>>> t
(12345, 54321, 'hello!')
>>> # Tuples may be nested:
... u = t, (1, 2, 3, 4, 5)
>>> u
((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))
>>> # Tuples are immutable:
... t[0] = 88888
```

```

Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> # but they can contain mutable objects:
... v = ([1, 2, 3], [3, 2, 1])
>>> v
([1, 2, 3], [3, 2, 1])

```

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are *immutable*, and usually contain an heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of `namedtuples`). Lists are *mutable*, and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

```

>>> empty = ()
>>> singleton = 'hello',      # <-- note trailing comma
>>> len(empty)
0
>>> len(singleton)
1
>>> singleton
('hello',)

```

The statement `t = 12345, 54321, 'hello!'` is an example of *tuple packing*: the values 12345, 54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

```
>>> x, y, z = t
```

This is called, appropriately enough, *sequence unpacking* and works for any sequence on the right-hand side. Sequence unpacking requires the list of variables on the left to have the same number of elements as the length of the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4 Sets

Python also includes a data type for *sets*. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Here is a brief demonstration:

```

>>> basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']
>>> fruit = set(basket)          # create a set without duplicates
>>> fruit
set(['orange', 'pear', 'apple', 'banana'])
>>> 'orange' in fruit           # fast membership testing
True
>>> 'crabgrass' in fruit
False

```

```
>>> # Demonstrate set operations on unique letters from two words
...
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a                                     # unique letters in a
set(['a', 'r', 'b', 'c', 'd'])
>>> a - b                                 # letters in a but not in b
set(['r', 'd', 'b'])
>>> a | b                                 # letters in either a or b
set(['a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'])
>>> a & b                                 # letters in both a and b
set(['a', 'c'])
>>> a ^ b                                 # letters in a or b but not both
set(['r', 'd', 'b', 'm', 'z', 'l'])
```

## 5.5 Dictionaries

Another useful data type built into Python is the *dictionary* (see *typesmapping*). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by *keys*, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like `append()` and `extend()`.

It is best to think of a dictionary as an unordered set of *key: value* pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: `{}`. Placing a comma-separated list of *key:value* pairs within the braces adds initial *key:value* pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a *key:value* pair with `del`. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

The `keys()` method of a dictionary object returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just apply the `sorted()` function to it). To check whether a single key is in the dictionary, use the `in` keyword.

Here is a small example using a dictionary:

```
>>> tel = {'jack': 4098, 'sape': 4139}
>>> tel['guido'] = 4127
>>> tel
{'sape': 4139, 'guido': 4127, 'jack': 4098}
>>> tel['jack']
4098
>>> del tel['sape']
>>> tel['irv'] = 4127
>>> tel
{'guido': 4127, 'irv': 4127, 'jack': 4098}
>>> tel.keys()
['guido', 'irv', 'jack']
>>> 'guido' in tel
True
```



```
apple
banana
orange
pear
```

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the `iteritems()` method.

```
>>> knights = {'gallahad': 'the pure', 'robin': 'the brave'}
>>> for k, v in knights.iteritems():
...     print k, v
...
gallahad the pure
robin the brave
```

## 5.7 More on Conditions

The conditions used in `while` and `if` statements can contain any operators, not just comparisons.

The comparison operators `in` and `not in` check whether a value occurs (does not occur) in a sequence. The operators `is` and `is not` compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, `a < b == c` tests whether `a` is less than `b` and moreover `b` equals `c`.

Comparisons may be combined using the Boolean operators `and` and `or`, and the outcome of a comparison (or of any other Boolean expression) may be negated with `not`. These have lower priorities than comparison operators; between them, `not` has the highest priority and `or` the lowest, so that `A and not B or C` is equivalent to `(A and (not B)) or C`. As always, parentheses can be used to express the desired composition.

The Boolean operators `and` and `or` are so-called *short-circuit* operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if `A` and `C` are true but `B` is false, `A and B and C` does not evaluate the expression `C`. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

```
>>> string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'
>>> non_null = string1 or string2 or string3
>>> non_null
'Trondheim'
```

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing `= in` an expression when `==` was intended.

## 5.8 Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses *lexicographical* ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the ASCII ordering for individual characters. Some examples of comparisons between sequences of the same type:

```
(1, 2, 3) < (1, 2, 4)
[1, 2, 3] < [1, 2, 4]
'ABC' < 'C' < 'Pascal' < 'Python'
(1, 2, 3, 4) < (1, 2, 4)
(1, 2) < (1, 2, -1)
(1, 2, 3) == (1.0, 2.0, 3.0)
(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)
```

Note that comparing objects of different types is legal. The outcome is deterministic but arbitrary: the types are ordered by their name. Thus, a list is always smaller than a string, a string is always smaller than a tuple, etc.<sup>1</sup> Mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc.

---

<sup>1</sup> The rules for comparing objects of different types should not be relied upon; they may change in a future version of the language.



# MODULES

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a *script*. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you've written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a *module*; definitions from a module can be *imported* into other modules or into the *main* module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix `.py` appended. Within a module, the module's name (as a string) is available as the value of the global variable `__name__`. For instance, use your favorite text editor to create a file called `fibonacci.py` in the current directory with the following contents:

```
# Fibonacci numbers module

def fib(n):    # write Fibonacci series up to n
    a, b = 0, 1
    while b < n:
        print b,
        a, b = b, a+b

def fib2(n): # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result
```

Now enter the Python interpreter and import this module with the following command:

```
>>> import fibo
```

This does not enter the names of the functions defined in `fibo` directly in the current symbol table; it only enters the module name `fibo` there. Using the module name you can access the functions:

```
>>> fibo.fib(1000)
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
>>> fibo.fib2(100)
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

```
>>> fibo.__name__
'fibo'
```

If you intend to use a function often you can assign it to a local name:

```
>>> fib = fibo.fib
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

## 6.1 More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the *first* time the module is imported somewhere.<sup>1</sup>

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user's global variables. On the other hand, if you know what you are doing you can touch a module's global variables with the same notation used to refer to its functions, `modname.itemname`.

Modules can import other modules. It is customary but not required to place all `import` statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module's global symbol table.

There is a variant of the `import` statement that imports names from a module directly into the importing module's symbol table. For example:

```
>>> from fibo import fib, fib2
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, `fibo` is not defined).

There is even a variant to import all names that a module defines:

```
>>> from fibo import *
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This imports all names except those beginning with an underscore (`_`).

Note that in general the practice of importing `*` from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

---

**Note:** For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it's just one module you want to test interactively, use `reload()`, e.g. `reload(modulename)`.

---

### 6.1.1 Executing modules as scripts

When you run a Python module with

```
python fibo.py <arguments>
```

---

<sup>1</sup> In fact function definitions are also 'statements' that are 'executed'; the execution of a module-level function enters the function name in the module's global symbol table.

the code in the module will be executed, just as if you imported it, but with the `__name__` set to `"__main__"`. That means that by adding this code at the end of your module:

```
if __name__ == "__main__":
    import sys
    fib(int(sys.argv[1]))
```

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

```
$ python fibo.py 50
1 1 2 3 5 8 13 21 34
```

If the module is imported, the code is not run:

```
>>> import fibo
>>>
```

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

## 6.1.2 The Module Search Path

When a module named `spam` is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named `spam.py` in a list of directories given by the variable `sys.path`. `sys.path` is initialized from these locations:

- the directory containing the input script (or the current directory).
- `PYTHONPATH` (a list of directory names, with the same syntax as the shell variable `PATH`).
- the installation-dependent default.

After initialization, Python programs can modify `sys.path`. The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section *Standard Modules* for more information.

## 6.1.3 “Compiled” Python files

As an important speed-up of the start-up time for short programs that use a lot of standard modules, if a file called `spam.pyc` exists in the directory where `spam.py` is found, this is assumed to contain an already-“byte-compiled” version of the module `spam`. The modification time of the version of `spam.py` used to create `spam.pyc` is recorded in `spam.pyc`, and the `.pyc` file is ignored if these don’t match.

Normally, you don’t need to do anything to create the `spam.pyc` file. Whenever `spam.py` is successfully compiled, an attempt is made to write the compiled version to `spam.pyc`. It is not an error if this attempt fails; if for any reason the file is not written completely, the resulting `spam.pyc` file will be recognized as invalid and thus ignored later. The contents of the `spam.pyc` file are platform independent, so a Python module directory can be shared by machines of different architectures.

Some tips for experts:

- When the Python interpreter is invoked with the `-O` flag, optimized code is generated and stored in `.pyo` files. The optimizer currently doesn’t help much; it only removes `assert` statements. When `-O` is used, *all bytecode* is optimized; `.pyc` files are ignored and `.py` files are compiled to optimized bytecode.
- Passing two `-O` flags to the Python interpreter (`-OO`) will cause the bytecode compiler to perform optimizations that could in some rare cases result in malfunctioning programs. Currently only `__doc__` strings are removed

from the bytecode, resulting in more compact `.pyo` files. Since some programs may rely on having these available, you should only use this option if you know what you're doing.

- A program doesn't run any faster when it is read from a `.pyc` or `.pyo` file than when it is read from a `.py` file; the only thing that's faster about `.pyc` or `.pyo` files is the speed with which they are loaded.
- When a script is run by giving its name on the command line, the bytecode for the script is never written to a `.pyc` or `.pyo` file. Thus, the startup time of a script may be reduced by moving most of its code to a module and having a small bootstrap script that imports that module. It is also possible to name a `.pyc` or `.pyo` file directly on the command line.
- It is possible to have a file called `spam.pyc` (or `spam.pyo` when `-O` is used) without a file `spam.py` for the same module. This can be used to distribute a library of Python code in a form that is moderately hard to reverse engineer.
- The module `compileall` can create `.pyc` files (or `.pyo` files when `-O` is used) for all modules in a directory.

## 6.2 Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference ("Library Reference" hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the `winreg` module is only provided on Windows systems. One particular module deserves some attention: `sys`, which is built into every Python interpreter. The variables `sys.ps1` and `sys.ps2` define the strings used as primary and secondary prompts:

```
>>> import sys
>>> sys.ps1
'>>> '
>>> sys.ps2
'... '
>>> sys.ps1 = 'C> '
C> print 'Yuck!'
Yuck!
C>
```

These two variables are only defined if the interpreter is in interactive mode.

The variable `sys.path` is a list of strings that determines the interpreter's search path for modules. It is initialized to a default path taken from the environment variable `PYTHONPATH`, or from a built-in default if

`PYTHONPATH` is not set. You can modify it using standard list operations:

```
>>> import sys
>>> sys.path.append('/ufs/guido/lib/python')
```

## 6.3 The `dir()` Function

The built-in function `dir()` is used to find out which names a module defines. It returns a sorted list of strings:

```
>>> import fibo, sys
>>> dir(fibo)
['__name__', 'fib', 'fib2']
>>> dir(sys)
['__displayhook__', '__doc__', '__excepthook__', '__name__', '__stderr__',
```

```
'__stdin__', '__stdout__', '_getframe', 'api_version', 'argv',
'builtin_module_names', 'byteorder', 'callstats', 'copyright',
'displayhook', 'exc_clear', 'exc_info', 'exc_type', 'excepthook',
'exec_prefix', 'executable', 'exit', 'getdefaultencoding', 'getdlopenflags',
'getrecursionlimit', 'getrefcount', 'hexversion', 'maxint', 'maxunicode',
'meta_path', 'modules', 'path', 'path_hooks', 'path_importer_cache',
'platform', 'prefix', 'ps1', 'ps2', 'setcheckinterval', 'setdlopenflags',
'setprofile', 'setrecursionlimit', 'settrace', 'stderr', 'stdin', 'stdout',
'version', 'version_info', 'warnoptions']
```

Without arguments, `dir()` lists the names you have defined currently:

```
>>> a = [1, 2, 3, 4, 5]
>>> import fibo
>>> fib = fibo.fib
>>> dir()
['__builtins__', '__doc__', '__file__', '__name__', 'a', 'fib', 'fibo', 'sys']
```

Note that it lists all types of names: variables, modules, functions, etc.

`dir()` does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module `__builtin__`:

```
>>> import __builtin__
>>> dir(__builtin__)
['ArithmeticError', 'AssertionError', 'AttributeError', 'DeprecationWarning',
'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',
'FloatingPointError', 'FutureWarning', 'IOError', 'ImportError',
'IndentationError', 'IndexError', 'KeyError', 'KeyboardInterrupt',
'LookupError', 'MemoryError', 'NameError', 'None', 'NotImplemented',
'NotImplementedError', 'OSError', 'OverflowError',
'PendingDeprecationWarning', 'ReferenceError', 'RuntimeError',
'RuntimeWarning', 'StandardError', 'StopIteration', 'SyntaxError',
'SyntaxWarning', 'SystemError', 'SystemExit', 'TabError', 'True',
'TypeError', 'UnboundLocalError', 'UnicodeDecodeError',
'UnicodeEncodeError', 'UnicodeError', 'UnicodeTranslateError',
'UserWarning', 'ValueError', 'Warning', 'WindowsError',
'ZeroDivisionError', '_', '__debug__', '__doc__', '__import__',
'__name__', 'abs', 'apply', 'basestring', 'bool', 'buffer',
'callable', 'chr', 'classmethod', 'cmp', 'coerce', 'compile',
'complex', 'copyright', 'credits', 'delattr', 'dict', 'dir', 'divmod',
'enumerate', 'eval', 'execfile', 'exit', 'file', 'filter', 'float',
'frozenset', 'getattr', 'globals', 'hasattr', 'hash', 'help', 'hex',
'id', 'input', 'int', 'intern', 'isinstance', 'issubclass', 'iter',
'len', 'license', 'list', 'locals', 'long', 'map', 'max', 'memoryview',
'min', 'object', 'oct', 'open', 'ord', 'pow', 'property', 'quit', 'range',
'raw_input', 'reduce', 'reload', 'repr', 'reversed', 'round', 'set',
'setattr', 'slice', 'sorted', 'staticmethod', 'str', 'sum', 'super',
'tuple', 'type', 'unichr', 'unicode', 'vars', 'xrange', 'zip']
```

## 6.4 Packages

Packages are a way of structuring Python's module namespace by using "dotted module names". For example, the module name `A.B` designates a submodule named `B` in a package named `A`. Just like the use of modules saves the authors of different modules from having to worry about each other's global variable names, the use of dotted module

names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other's module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: `.wav`, `.aiff`, `.au`), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here's a possible structure for your package (expressed in terms of a hierarchical filesystem):

```
sound/                                Top-level package
  __init__.py                          Initialize the sound package
  formats/                              Subpackage for file format conversions
    __init__.py
    wavread.py
    wavwrite.py
    aiffread.py
    aiffwrite.py
    auread.py
    auwrite.py
    ...
  effects/                              Subpackage for sound effects
    __init__.py
    echo.py
    surround.py
    reverse.py
    ...
  filters/                              Subpackage for filters
    __init__.py
    equalizer.py
    vocoder.py
    karaoke.py
    ...
```

When importing the package, Python searches through the directories on `sys.path` looking for the package subdirectory.

The `__init__.py` files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as `string`, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, `__init__.py` can just be an empty file, but it can also execute initialization code for the package or set the `__all__` variable, described later.

Users of the package can import individual modules from the package, for example:

```
import sound.effects.echo
```

This loads the submodule `sound.effects.echo`. It must be referenced with its full name.

```
sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)
```

An alternative way of importing the submodule is:

```
from sound.effects import echo
```

This also loads the submodule `echo`, and makes it available without its package prefix, so it can be used as follows:

```
echo.echofilter(input, output, delay=0.7, atten=4)
```

Yet another variation is to import the desired function or variable directly:

```
from sound.effects.echo import echofilter
```

Again, this loads the submodule `echo`, but this makes its function `echofilter()` directly available:

```
echofilter(input, output, delay=0.7, atten=4)
```

Note that when using `from package import item`, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The `import` statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an `ImportError` exception is raised.

Contrarily, when using syntax like `import item.subitem.subsubitem`, each item except for the last must be a package; the last item can be a module or a package but can't be a class or function or variable defined in the previous item.

### 6.4.1 Importing \* From a Package

Now what happens when the user writes `from sound.effects import *`? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The `import` statement uses the following convention: if a package's `__init__.py` code defines a list named `__all__`, it is taken to be the list of module names that should be imported when `from package import *` is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don't see a use for importing `*` from their package. For example, the file `sounds/effects/__init__.py` could contain the following code:

```
__all__ = ["echo", "surround", "reverse"]
```

This would mean that `from sound.effects import *` would import the three named submodules of the `sound` package.

If `__all__` is not defined, the statement `from sound.effects import *` does *not* import all submodules from the package `sound.effects` into the current namespace; it only ensures that the package `sound.effects` has been imported (possibly running any initialization code in `__init__.py`) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by `__init__.py`. It also includes any submodules of the package that were explicitly loaded by previous `import` statements. Consider this code:

```
import sound.effects.echo
import sound.effects.surround
from sound.effects import *
```

In this example, the `echo` and `surround` modules are imported in the current namespace because they are defined in the `sound.effects` package when the `from...import` statement is executed. (This also works when `__all__` is defined.)

Although certain modules are designed to export only names that follow certain patterns when you use `import *`, it is still considered bad practise in production code.

Remember, there is nothing wrong with using `from Package import specific_submodule!` In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

## 6.4.2 Intra-package References

The submodules often need to refer to each other. For example, the `surround` module might use the `echo` module. In fact, such references are so common that the `import` statement first looks in the containing package before looking in the standard module search path. Thus, the `surround` module can simply use `import echo` or `from echo import echofilter`. If the imported module is not found in the current package (the package of which the current module is a submodule), the `import` statement looks for a top-level module with the given name.

When packages are structured into subpackages (as with the `sound` package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the module `sound.filters.vocoder` needs to use the `echo` module in the `sound.effects` package, it can use `from sound.effects import echo`.

Starting with Python 2.5, in addition to the implicit relative imports described above, you can write explicit relative imports with the `from module import name` form of `import` statement. These explicit relative imports use leading dots to indicate the current and parent packages involved in the relative import. From the `surround` module for example, you might use:

```
from . import echo
from .. import formats
from ..filters import equalizer
```

Note that both explicit and implicit relative imports are based on the name of the current module. Since the name of the main module is always `"__main__"`, modules intended for use as the main module of a Python application should always use absolute imports.

## 6.4.3 Packages in Multiple Directories

Packages support one more special attribute, `__path__`. This is initialized to be a list containing the name of the directory holding the package's `__init__.py` before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

# INPUT AND OUTPUT

There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities.

## 7.1 Fancier Output Formatting

So far we've encountered two ways of writing values: *expression statements* and the `print` statement. (A third way is using the `write()` method of file objects; the standard output file can be referenced as `sys.stdout`. See the Library Reference for more information on this.)

Often you'll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string types have some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the `str.format()` method.

The `string` module contains a `Template` class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the `repr()` or `str()` functions.

The `str()` function is meant to return representations of values which are fairly human-readable, while `repr()` is meant to generate representations which can be read by the interpreter (or will force a `SyntaxError` if there is no equivalent syntax). For objects which don't have a particular representation for human consumption, `str()` will return the same value as `repr()`. Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings and floating point numbers, in particular, have two distinct representations.

Some examples:

```
>>> s = 'Hello, world.'
>>> str(s)
'Hello, world.'
>>> repr(s)
"'Hello, world.'"
>>> str(1.0/7.0)
'0.142857142857'
>>> repr(1.0/7.0)
'0.14285714285714285'
>>> x = 10 * 3.25
>>> y = 200 * 200
>>> s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'
```

```
>>> print s
The value of x is 32.5, and y is 40000...
>>> # The repr() of a string adds string quotes and backslashes:
... hello = 'hello, world\n'
>>> hellos = repr(hello)
>>> print hellos
'hello, world\n'
>>> # The argument to repr() may be any Python object:
... repr((x, y, ('spam', 'eggs'))))
"(32.5, 40000, ('spam', 'eggs'))"
```

Here are two ways to write a table of squares and cubes:

```
>>> for x in range(1, 11):
...     print repr(x).rjust(2), repr(x*x).rjust(3),
...           # Note trailing comma on previous line
...           repr(x*x*x).rjust(4)
...
1  1  1
2  4  8
3  9 27
4 16 64
5 25125
6 36216
7 49343
8 64512
9 81729
10 1001000

>>> for x in range(1,11):
...     print '{0:2d} {1:3d} {2:4d}'.format(x, x*x, x*x*x)
...
1  1  1
2  4  8
3  9 27
4 16 64
5 25125
6 36216
7 49343
8 64512
9 81729
10 1001000
```

(Note that in the first example, one space between each column was added by the way `print` works: it always adds spaces between its arguments.)

This example demonstrates the `str.rjust()` method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods `str.ljust()` and `str.center()`. These methods do not write anything, they just return a new string. If the input string is too long, they don't truncate it, but return it unchanged; this will mess up your column lay-out but that's usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in `x.ljust(n)[:n]`.)

There is another method, `str.zfill()`, which pads a numeric string on the left with zeros. It understands about plus and minus signs:

```
>>> '12'.zfill(5)
```

```
'00012'
>>> '-3.14'.zfill(7)
'-003.14'
>>> '3.14159265359'.zfill(5)
'3.14159265359'
```

Basic usage of the `str.format()` method looks like this:

```
>>> print 'We are the {} who say "{}!"'.format('knights', 'Ni')
We are the knights who say "Ni!"
```

The brackets and characters within them (called format fields) are replaced with the objects passed into the `str.format()` method. A number in the brackets refers to the position of the object passed into the `str.format()` method.

```
>>> print '{0} and {1}'.format('spam', 'eggs')
spam and eggs
>>> print '{1} and {0}'.format('spam', 'eggs')
eggs and spam
```

If keyword arguments are used in the `str.format()` method, their values are referred to by using the name of the argument.

```
>>> print 'This {food} is {adjective}.'.format(
...     food='spam', adjective='absolutely horrible')
This spam is absolutely horrible.
```

Positional and keyword arguments can be arbitrarily combined:

```
>>> print 'The story of {0}, {1}, and {other}'.format('Bill', 'Manfred',
...                                               other='Georg')
The story of Bill, Manfred, and Georg.
```

'!s' (apply `str()`) and '!r' (apply `repr()`) can be used to convert the value before it is formatted.

```
>>> import math
>>> print 'The value of PI is approximately {}'.format(math.pi)
The value of PI is approximately 3.14159265359.
>>> print 'The value of PI is approximately {!r}'.format(math.pi)
The value of PI is approximately 3.141592653589793.
```

An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

```
>>> import math
>>> print 'The value of PI is approximately {:.3f}'.format(math.pi)
The value of PI is approximately 3.142.
```

Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}
>>> for name, phone in table.items():
...     print '{0:10} ==> {1:10d}'.format(name, phone)
...
Jack          ==>      4098
Dcab          ==>      7678
Sjoerd        ==>      4127
```

If you have a really long format string that you don't want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square

brackets `[]` to access the keys

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print ('Jack: {0[Jack]:d}; Sjoerd: {0[Sjoerd]:d}; '
...       'Dcab: {0[Dcab]:d}'.format(table))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This could also be done by passing the table as keyword arguments with the `**` notation.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print 'Jack: {Jack:d}; Sjoerd: {Sjoerd:d}; Dcab: {Dcab:d}'.format(**table)
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This is particularly useful in combination with the built-in function `vars()`, which returns a dictionary containing all local variables.

For a complete overview of string formatting with `str.format()`, see *formatstrings*.

## 7.1.1 Old string formatting

The `%` operator can also be used for string formatting. It interprets the left argument much like a `sprintf()`-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

```
>>> import math
>>> print 'The value of PI is approximately %5.3f.' % math.pi
The value of PI is approximately 3.142.
```

Since `str.format()` is quite new, a lot of Python code still uses the `%` operator. However, because this old style of formatting will eventually be removed from the language, `str.format()` should generally be used.

More information can be found in the *string-formatting* section.

## 7.2 Reading and Writing Files

`open()` returns a file object, and is most commonly used with two arguments: `open(filename, mode)`.

```
>>> f = open('/tmp/workfile', 'w')
>>> print f
<open file '/tmp/workfile', mode 'w' at 80a0960>
```

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. *mode* can be `'r'` when the file will only be read, `'w'` for only writing (an existing file with the same name will be erased), and `'a'` opens the file for appending; any data written to the file is automatically added to the end. `'r+'` opens the file for both reading and writing. The *mode* argument is optional; `'r'` will be assumed if it's omitted.

On Windows, `'b'` appended to the mode opens the file in binary mode, so there are also modes like `'rb'`, `'wb'`, and `'r+b'`. Python on Windows makes a distinction between text and binary files; the end-of-line characters in text files are automatically altered slightly when data is read or written. This behind-the-scenes modification to file data is fine for ASCII text files, but it'll corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files. On Unix, it doesn't hurt to append a `'b'` to the mode, so you can use it platform-independently for all binary files.

## 7.2.1 Methods of File Objects

The rest of the examples in this section will assume that a file object called `f` has already been created.

To read a file's contents, call `f.read(size)`, which reads some quantity of data and returns it as a string. *size* is an optional numeric argument. When *size* is omitted or negative, the entire contents of the file will be read and returned; it's your problem if the file is twice as large as your machine's memory. Otherwise, at most *size* bytes are read and returned. If the end of the file has been reached, `f.read()` will return an empty string (`""`).

```
>>> f.read()
'This is the entire file.\n'
>>> f.read()
''
```

`f.readline()` reads a single line from the file; a newline character (`\n`) is left at the end of the string, and is only omitted on the last line of the file if the file doesn't end in a newline. This makes the return value unambiguous; if `f.readline()` returns an empty string, the end of the file has been reached, while a blank line is represented by `'\n'`, a string containing only a single newline.

```
>>> f.readline()
'This is the first line of the file.\n'
>>> f.readline()
'Second line of the file\n'
>>> f.readline()
''
```

`f.readlines()` returns a list containing all the lines of data in the file. If given an optional parameter *sizehint*, it reads that many bytes from the file and enough more to complete a line, and returns the lines from that. This is often used to allow efficient reading of a large file by lines, but without having to load the entire file in memory. Only complete lines will be returned.

```
>>> f.readlines()
['This is the first line of the file.\n', 'Second line of the file\n']
```

An alternative approach to reading lines is to loop over the file object. This is memory efficient, fast, and leads to simpler code:

```
>>> for line in f:
    print line,
```

```
This is the first line of the file.
Second line of the file
```

The alternative approach is simpler but does not provide as fine-grained control. Since the two approaches manage line buffering differently, they should not be mixed.

`f.write(string)` writes the contents of *string* to the file, returning `None`.

```
>>> f.write('This is a test\n')
```

To write something other than a string, it needs to be converted to a string first:

```
>>> value = ('the answer', 42)
>>> s = str(value)
>>> f.write(s)
```

`f.tell()` returns an integer giving the file object's current position in the file, measured in bytes from the beginning of the file. To change the file object's position, use `f.seek(offset, from_what)`. The position is computed from adding *offset* to a reference point; the reference point is selected by the *from\_what* argument. A *from\_what* value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. *from\_what* can be omitted and defaults to 0, using the beginning of the file as the reference point.

```
>>> f = open('/tmp/workfile', 'r+')
>>> f.write('0123456789abcdef')
>>> f.seek(5)          # Go to the 6th byte in the file
>>> f.read(1)
'5'
>>> f.seek(-3, 2)     # Go to the 3rd byte before the end
>>> f.read(1)
'd'
```

When you're done with a file, call `f.close()` to close it and free up any system resources taken up by the open file. After calling `f.close()`, attempts to use the file object will automatically fail.

```
>>> f.close()
>>> f.read()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: I/O operation on closed file
```

It is good practice to use the `with` keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent `try-finally` blocks:

```
>>> with open('/tmp/workfile', 'r') as f:
...     read_data = f.read()
>>> f.closed
True
```

File objects have some additional methods, such as `isatty()` and `truncate()` which are less frequently used; consult the Library Reference for a complete guide to file objects.

## 7.2.2 The `pickle` Module

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the `read()` method only returns strings, which will have to be passed to a function like `int()`, which takes a string like `'123'` and returns its numeric value 123. However, when you want to save more complex data types like lists, dictionaries, or class instances, things get a lot more complicated.

Rather than have users be constantly writing and debugging code to save complicated data types, Python provides a standard module called `pickle`. This is an amazing module that can take almost any Python object (even some forms of Python code!), and convert it to a string representation; this process is called *pickling*. Reconstructing the object from the string representation is called *unpickling*. Between pickling and unpickling, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

If you have an object `x`, and a file object `f` that's been opened for writing, the simplest way to pickle the object takes only one line of code:

```
pickle.dump(x, f)
```

To unpickle the object again, if `f` is a file object which has been opened for reading:

```
x = pickle.load(f)
```

(There are other variants of this, used when pickling many objects or when you don't want to write the pickled data to a file; consult the complete documentation for `pickle` in the Python Library Reference.)

`pickle` is the standard way to make Python objects which can be stored and reused by other programs or by a future invocation of the same program; the technical term for this is a *persistent* object. Because `pickle` is so widely used, many authors who write Python extensions take care to ensure that new data types such as matrices can be properly pickled and unpickled.

# ERRORS AND EXCEPTIONS

Until now error messages haven't been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: *syntax errors* and *exceptions*.

## 8.1 Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

```
>>> while True print 'Hello world'
      File "<stdin>", line 1, in ?
          while True print 'Hello world'
                          ^
SyntaxError: invalid syntax
```

The parser repeats the offending line and displays a little 'arrow' pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token *preceding* the arrow: in the example, the error is detected at the keyword `print`, since a colon (`:`) is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2 Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called *exceptions* and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

```
>>> 10 * (1/0)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ZeroDivisionError: integer division or modulo by zero
>>> 4 + spam*3
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: name 'spam' is not defined
>>> '2' + 2
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: cannot concatenate 'str' and 'int' objects
```

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are `ZeroDivisionError`, `NameError` and `TypeError`. The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

`builtin-exceptions` lists the built-in exceptions and their meanings.

## 8.3 Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using `Control-C` or whatever the operating system supports); note that a user-generated interruption is signalled by raising the `KeyboardInterrupt` exception.

```
>>> while True:
...     try:
...         x = int(raw_input("Please enter a number: "))
...         break
...     except ValueError:
...         print "Oops! That was no valid number. Try again..."
... 
```

The `try` statement works as follows.

- First, the *try clause* (the statement(s) between the `try` and `except` keywords) is executed.
- If no exception occurs, the *except clause* is skipped and execution of the `try` statement is finished.
- If an exception occurs during execution of the `try` clause, the rest of the clause is skipped. Then if its type matches the exception named after the `except` keyword, the `except` clause is executed, and then execution continues after the `try` statement.
- If an exception occurs which does not match the exception named in the `except` clause, it is passed on to outer `try` statements; if no handler is found, it is an *unhandled exception* and execution stops with a message as shown above.

A `try` statement may have more than one `except` clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding `try` clause, not in other handlers of the same `try` statement. An `except` clause may name multiple exceptions as a parenthesized tuple, for example:

```
... except (RuntimeError, TypeError, NameError):
...     pass
```

Note that the parentheses around this tuple are required, because `except ValueError, e:` was the syntax used for what is normally written as `except ValueError as e:` in modern Python (described below). The old syntax is still supported for backwards compatibility. This means `except RuntimeError, TypeError:` is not equivalent to `except (RuntimeError, TypeError):` but to `except RuntimeError as TypeError:` which is not what you want.

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

```
import sys

try:
    f = open('myfile.txt')
    s = f.readline()
    i = int(s.strip())
except IOError as e:
    print "I/O error({0}): {1}".format(e.errno, e.strerror)
except ValueError:
    print "Could not convert data to an integer."
except:
    print "Unexpected error:", sys.exc_info()[0]
    raise
```

The try ... except statement has an optional *else clause*, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

```
for arg in sys.argv[1:]:
    try:
        f = open(arg, 'r')
    except IOError:
        print 'cannot open', arg
    else:
        print arg, 'has', len(f.readlines()), 'lines'
        f.close()
```

The use of the else clause is better than adding additional code to the try clause because it avoids accidentally catching an exception that wasn't raised by the code being protected by the try ... except statement.

When an exception occurs, it may have an associated value, also known as the exception's *argument*. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name (or tuple). The variable is bound to an exception instance with the arguments stored in `instance.args`. For convenience, the exception instance defines `__str__()` so the arguments can be printed directly without having to reference `.args`.

One may also instantiate an exception first before raising it and add any attributes to it as desired.

```
>>> try:
...     raise Exception('spam', 'eggs')
... except Exception as inst:
...     print type(inst)         # the exception instance
...     print inst.args         # arguments stored in .args
...     print inst              # __str__ allows args to printed directly
...     x, y = inst.args
...     print 'x =', x
...     print 'y =', y
...
<type 'exceptions.Exception'>
('spam', 'eggs')
('spam', 'eggs')
x = spam
y = eggs
```

If an exception has an argument, it is printed as the last part ('detail') of the message for unhandled exceptions.

Exception handlers don't just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

```
>>> def this_fails():
...     x = 1/0
...
>>> try:
...     this_fails()
... except ZeroDivisionError as detail:
...     print 'Handling run-time error:', detail
...
Handling run-time error: integer division or modulo by zero
```

## 8.4 Raising Exceptions

The `raise` statement allows the programmer to force a specified exception to occur. For example:

```
>>> raise NameError('HiThere')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: HiThere
```

The sole argument to `raise` indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from `Exception`).

If you need to determine whether an exception was raised but don't intend to handle it, a simpler form of the `raise` statement allows you to re-raise the exception:

```
>>> try:
...     raise NameError('HiThere')
... except NameError:
...     print 'An exception flew by!'
...     raise
...
An exception flew by!
Traceback (most recent call last):
  File "<stdin>", line 2, in ?
NameError: HiThere
```

## 8.5 User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see *Classes* for more about Python classes). Exceptions should typically be derived from the `Exception` class, either directly or indirectly. For example:

```
>>> class MyError(Exception):
...     def __init__(self, value):
...         self.value = value
...     def __str__(self):
...         return repr(self.value)
...
>>> try:
...     raise MyError(2*2)
```

```

... except MyError as e:
...     print 'My exception occurred, value:', e.value
...
My exception occurred, value: 4
>>> raise MyError('oops!')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
__main__.MyError: 'oops!'

```

In this example, the default `__init__()` of `Exception` has been overridden. The new behavior simply creates the `value` attribute. This replaces the default behavior of creating the `args` attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

```

class Error(Exception):
    """Base class for exceptions in this module."""
    pass

class InputError(Error):
    """Exception raised for errors in the input.

    Attributes:
        expr -- input expression in which the error occurred
        msg  -- explanation of the error
    """

    def __init__(self, expr, msg):
        self.expr = expr
        self.msg = msg

class TransitionError(Error):
    """Raised when an operation attempts a state transition that's not
    allowed.

    Attributes:
        prev -- state at beginning of transition
        next -- attempted new state
        msg  -- explanation of why the specific transition is not allowed
    """

    def __init__(self, prev, next, msg):
        self.prev = prev
        self.next = next
        self.msg = msg

```

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter *Classes*.

## 8.6 Defining Clean-up Actions

The `try` statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

```
>>> try:
...     raise KeyboardInterrupt
... finally:
...     print 'Goodbye, world!'
...
Goodbye, world!
KeyboardInterrupt
```

A *finally clause* is always executed before leaving the `try` statement, whether an exception has occurred or not. When an exception has occurred in the `try` clause and has not been handled by an `except` clause (or it has occurred in a `except` or `else` clause), it is re-raised after the `finally` clause has been executed. The `finally` clause is also executed “on the way out” when any other clause of the `try` statement is left via a `break`, `continue` or `return` statement. A more complicated example (having `except` and `finally` clauses in the same `try` statement works as of Python 2.5):

```
>>> def divide(x, y):
...     try:
...         result = x / y
...     except ZeroDivisionError:
...         print "division by zero!"
...     else:
...         print "result is", result
...     finally:
...         print "executing finally clause"
...
>>> divide(2, 1)
result is 2
executing finally clause
>>> divide(2, 0)
division by zero!
executing finally clause
>>> divide("2", "1")
executing finally clause
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 3, in divide
TypeError: unsupported operand type(s) for /: 'str' and 'str'
```

As you can see, the `finally` clause is executed in any event. The `TypeError` raised by dividing two strings is not handled by the `except` clause and therefore re-raised after the `finally` clause has been executed.

In real world applications, the `finally` clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7 Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

```
for line in open("myfile.txt"):
    print line
```

The problem with this code is that it leaves the file open for an indeterminate amount of time after the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The `with` statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

```
with open("myfile.txt") as f:
    for line in f:
        print line
```

After the statement is executed, the file `f` is always closed, even if a problem was encountered while processing the lines. Other objects which provide predefined clean-up actions will indicate this in their documentation.



---

# CLASSES

Compared with other programming languages, Python's class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are *public* (except see below *Private Variables and Class-local References*), and all member functions are *virtual*. As in Modula-3, there are no shorthands for referencing the object's members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1 A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2 Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python's scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what's going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let's begin with some definitions.

A *namespace* is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that's normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as `abs()`, and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function `maximize` without confusion — users of the modules must prefix it with the module name.

By the way, I use the word *attribute* for any name following a dot — for example, in the expression `z.real`, `real` is an attribute of the object `z`. Strictly speaking, references to names in modules are attribute references: in the expression `modname.funcname`, `modname` is a module object and `funcname` is an attribute of it. In this case there happens to be a straightforward mapping between the module's attributes and the global names defined in the module: they share the same namespace!<sup>1</sup>

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write `modname.the_answer = 42`. Writable attributes may also be deleted with the `del` statement. For example, `del modname.the_answer` will remove the attribute `the_answer` from the object named by `modname`.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called `__main__`, so they have their own global namespace. (The built-in names actually also live in a module; this is called `__builtin__`.)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A *scope* is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

- the innermost scope, which is searched first, contains the local names
- the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
- the next-to-last scope contains the current module's global names
- the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module's global names. Otherwise, all variables found outside of the innermost scope are read-only (an attempt to write to such a variable will simply create a *new* local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module's namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module's namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static

---

<sup>1</sup> Except for one thing. Module objects have a secret read-only attribute called `__dict__` which returns the dictionary used to implement the module's namespace; the name `__dict__` is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers.

name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no `global` statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement `del x` removes the binding of `x` from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, `import` statements and function definitions bind the module or function name in the local scope. (The `global` statement can be used to indicate that particular variables live in the global scope.)

## 9.3 A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1 Class Definition Syntax

The simplest form of class definition looks like this:

```
class ClassName:
    <statement-1>
    .
    .
    .
    <statement-N>
```

Class definitions, like function definitions (`def` statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an `if` statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the `end`), a *class object* is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (`ClassName` in the example).

### 9.3.2 Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

*Attribute references* use the standard syntax used for all attribute references in Python: `obj.name`. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

```
class MyClass:
    """A simple example class"""
    i = 12345
    def f(self):
        return 'hello world'
```

then `MyClass.i` and `MyClass.f` are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value of `MyClass.i` by assignment. `__doc__` is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class *instantiation* uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

```
x = MyClass()
```

creates a new *instance* of the class and assigns this object to the local variable `x`.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named `__init__()`, like this:

```
def __init__(self):
    self.data = []
```

When a class defines an `__init__()` method, class instantiation automatically invokes `__init__()` for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

```
x = MyClass()
```

Of course, the `__init__()` method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to `__init__()`. For example,

```
>>> class Complex:
...     def __init__(self, realpart, imagpart):
...         self.r = realpart
...         self.i = imagpart
...
>>> x = Complex(3.0, -4.5)
>>> x.r, x.i
(3.0, -4.5)
```

### 9.3.3 Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

*data attributes* correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if `x` is the instance of `MyClass` created above, the following piece of code will print the value 16, without leaving a trace:

```
x.counter = 1
while x.counter < 10:
    x.counter = x.counter * 2
print x.counter
del x.counter
```

The other kind of instance attribute reference is a *method*. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called `append`, `insert`, `remove`, `sort`, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, `x.f` is a valid method reference, since `MyClass.f` is a function, but `x.i` is not, since `MyClass.i` is not. But `x.f` is not the same thing as `MyClass.f` — it is a *method object*, not a function object.

### 9.3.4 Method Objects

Usually, a method is called right after it is bound:

```
x.f()
```

In the `MyClass` example, this will return the string `'hello world'`. However, it is not necessary to call a method right away: `x.f` is a method object, and can be stored away and called at a later time. For example:

```
xf = x.f
while True:
    print xf()
```

will continue to print `hello world` until the end of time.

What exactly happens when a method is called? You may have noticed that `x.f()` was called without an argument above, even though the function definition for `f()` specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn't actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call `x.f()` is exactly equivalent to `MyClass.f(x)`. In general, calling a method with a list of  $n$  arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method's object before the first argument.

If you still don't understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn't a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

## 9.4 Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users ("clients") of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called `self`. This is nothing more than a convention: the name `self` has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a *class browser* program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

```
# Function defined outside the class
def f1(self, x, y):
    return min(x, x+y)

class C:
    f = f1
    def g(self):
        return 'hello world'
    h = g
```

Now `f`, `g` and `h` are all attributes of class `C` that refer to function objects, and consequently they are all methods of instances of `C` — `h` being exactly equivalent to `g`. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the `self` argument:

```
class Bag:
    def __init__(self):
        self.data = []
    def add(self, x):
        self.data.append(x)
    def addtwice(self, x):
        self.add(x)
        self.add(x)
```

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we'll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a *class* (also called its *type*). It is stored as `object.__class__`.

## 9.5 Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

```
class DerivedClassName(BaseClassName):
    <statement-1>
    .
    .
    .
    <statement-N>
```

The name `BaseClassName` must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

```
class DerivedClassName(modname.BaseClassName):
```

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There's nothing special about instantiation of derived classes: `DerivedClassName()` creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively *virtual*.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just call `BaseClassName.methodname(self, arguments)`. This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as `BaseClassName` in the global scope.)

Python has two built-in functions that work with inheritance:

- Use `isinstance()` to check an instance's type: `isinstance(obj, int)` will be `True` only if `obj.__class__` is `int` or some class derived from `int`.
- Use `issubclass()` to check class inheritance: `issubclass(bool, int)` is `True` since `bool` is a subclass of `int`. However, `issubclass(unicode, str)` is `False` since `unicode` is not a subclass of `str` (they only share a common ancestor, `basestring`).

## 9.5.1 Multiple Inheritance

Python supports a limited form of multiple inheritance as well. A class definition with multiple base classes looks like this:

```
class DerivedClassName(Base1, Base2, Base3):
    <statement-1>
    .
    .
    .
    <statement-N>
```

For old-style classes, the only rule is depth-first, left-to-right. Thus, if an attribute is not found in `DerivedClassName`, it is searched in `Base1`, then (recursively) in the base classes of `Base1`, and only if it is not found there, it is searched in `Base2`, and so on.

(To some people breadth first — searching `Base2` and `Base3` before the base classes of `Base1` — looks more natural. However, this would require you to know whether a particular attribute of `Base1` is actually defined in `Base1` or in one of its base classes before you can figure out the consequences of a name conflict with an attribute of `Base2`. The depth-first rule makes no differences between direct and inherited attributes of `Base1`.)

For *new-style classes*, the method resolution order changes dynamically to support cooperative calls to `super()`. This approach is known in some other multiple-inheritance languages as *call-next-method* and is more powerful than the *super* call found in single-inheritance languages.

With new-style classes, dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all new-style classes inherit from `object`, so any case of multiple inheritance provides more than one path to reach `object`. To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the

precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <http://www.python.org/download/releases/2.3/mro/>.

## 9.6 Private Variables and Class-local References

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. `_spam`) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called *name mangling*. Any identifier of the form `__spam` (at least two leading underscores, at most one trailing underscore) is textually replaced with `__classname__spam`, where `classname` is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

```
class Mapping:
    def __init__(self, iterable):
        self.items_list = []
        self.__update(iterable)

    def update(self, iterable):
        for item in iterable:
            self.items_list.append(item)

    __update = update    # private copy of original update() method

class MappingSubclass(Mapping):

    def update(self, keys, values):
        # provides new signature for update()
        # but does not break __init__()
        for item in zip(keys, values):
            self.items_list.append(item)
```

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to `exec`, `eval()` or `execfile()` does not consider the `classname` of the invoking class to be the current class; this is similar to the effect of the `global` statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to `getattr()`, `setattr()` and `delattr()`, as well as when referencing `__dict__` directly.

## 9.7 Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

```
class Employee:
    pass
```

```

john = Employee() # Create an empty employee record

# Fill the fields of the record
john.name = 'John Doe'
john.dept = 'computer lab'
john.salary = 1000

```

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods `read()` and `readline()` that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: `m.im_self` is the instance object with the method `m()`, and `m.im_func` is the function object corresponding to the method.

## 9.8 Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the `raise` statement:

```
raise Class, instance
```

```
raise instance
```

In the first form, `instance` must be an instance of `Class` or of a class derived from it. The second form is a shorthand for:

```
raise instance.__class__, instance
```

A class in an `except` clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an `except` clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

```

class B:
    pass
class C(B):
    pass
class D(C):
    pass

for c in [B, C, D]:
    try:
        raise c()
    except D:
        print "D"
    except C:
        print "C"
    except B:
        print "B"

```

Note that if the `except` clauses were reversed (with `except B` first), it would have printed B, B, B — the first matching `except` clause is triggered.

When an error message is printed for an unhandled exception, the exception's class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function `str()`.

## 9.9 Iterators

By now you have probably noticed that most container objects can be looped over using a `for` statement:

```
for element in [1, 2, 3]:
    print element
for element in (1, 2, 3):
    print element
for key in {'one':1, 'two':2}:
    print key
for char in "123":
    print char
for line in open("myfile.txt"):
    print line
```

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the `for` statement calls `iter()` on the container object. The function returns an iterator object that defines the method `next()` which accesses elements in the container one at a time. When there are no more elements, `next()` raises a `StopIteration` exception which tells the `for` loop to terminate. This example shows how it all works:

```
>>> s = 'abc'
>>> it = iter(s)
>>> it
<iterator object at 0x00A1DB50>
>>> it.next()
'a'
>>> it.next()
'b'
>>> it.next()
'c'
>>> it.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
    it.next()
```

### StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an `__iter__()` method which returns an object with a `next()` method. If the class defines `next()`, then `__iter__()` can just return `self`:

```
class Reverse:
    """Iterator for looping over a sequence backwards."""
    def __init__(self, data):
        self.data = data
        self.index = len(data)
    def __iter__(self):
        return self
    def next(self):
        if self.index == 0:
            raise StopIteration
```

```

        self.index = self.index - 1
        return self.data[self.index]
>>> rev = Reverse('spam')
>>> iter(rev)
<__main__.Reverse object at 0x00A1DB50>
>>> for char in rev:
...     print char
...
m
a
p
s

```

## 9.10 Generators

*Generators* are a simple and powerful tool for creating iterators. They are written like regular functions but use the `yield` statement whenever they want to return data. Each time `next()` is called, the generator resumes where it left-off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

```

def reverse(data):
    for index in range(len(data)-1, -1, -1):
        yield data[index]
>>> for char in reverse('golf'):
...     print char
...
f
l
o
g

```

Anything that can be done with generators can also be done with class based iterators as described in the previous section. What makes generators so compact is that the `__iter__()` and `next()` methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like `self.index` and `self.data`.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise `StopIteration`. In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11 Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

```

>>> sum(i*i for i in range(10))           # sum of squares
285

```

```
>>> xvec = [10, 20, 30]
>>> yvec = [7, 5, 3]
>>> sum(x*y for x,y in zip(xvec, yvec))           # dot product
260

>>> from math import pi, sin
>>> sine_table = dict((x, sin(x*pi/180)) for x in range(0, 91))

>>> unique_words = set(word for line in page for word in line.split())

>>> valedictorian = max((student.gpa, student.name) for student in graduates)

>>> data = 'golf'
>>> list(data[i] for i in range(len(data)-1,-1,-1))
['f', 'l', 'o', 'g']
```

# BRIEF TOUR OF THE STANDARD LIBRARY

## 10.1 Operating System Interface

The `os` module provides dozens of functions for interacting with the operating system:

```
>>> import os
>>> os.getcwd()           # Return the current working directory
'C:\\Python26'
>>> os.chdir('/server/accesslogs') # Change current working directory
>>> os.system('mkdir today')      # Run the command mkdir in the system shell
0
```

Be sure to use the `import os` style instead of `from os import *`. This will keep `os.open()` from shadowing the built-in `open()` function which operates much differently.

The built-in `dir()` and `help()` functions are useful as interactive aids for working with large modules like `os`:

```
>>> import os
>>> dir(os)
<returns a list of all module functions>
>>> help(os)
<returns an extensive manual page created from the module's docstrings>
```

For daily file and directory management tasks, the `shutil` module provides a higher level interface that is easier to use:

```
>>> import shutil
>>> shutil.copyfile('data.db', 'archive.db')
>>> shutil.move('/build/executables', 'installdir')
```

## 10.2 File Wildcards

The `glob` module provides a function for making file lists from directory wildcard searches:

```
>>> import glob
>>> glob.glob('*.py')
['primes.py', 'random.py', 'quote.py']
```

## 10.3 Command Line Arguments

Common utility scripts often need to process command line arguments. These arguments are stored in the `sys` module's `argv` attribute as a list. For instance the following output results from running `python demo.py one two three` at the command line:

```
>>> import sys
>>> print sys.argv
['demo.py', 'one', 'two', 'three']
```

The `getopt` module processes `sys.argv` using the conventions of the Unix `getopt()` function. More powerful and flexible command line processing is provided by the `argparse` module.

## 10.4 Error Output Redirection and Program Termination

The `sys` module also has attributes for `stdin`, `stdout`, and `stderr`. The latter is useful for emitting warnings and error messages to make them visible even when `stdout` has been redirected:

```
>>> sys.stderr.write('Warning, log file not found starting a new one\n')
Warning, log file not found starting a new one
```

The most direct way to terminate a script is to use `sys.exit()`.

## 10.5 String Pattern Matching

The `re` module provides regular expression tools for advanced string processing. For complex matching and manipulation, regular expressions offer succinct, optimized solutions:

```
>>> import re
>>> re.findall(r'\bf[a-z]*', 'which foot or hand fell fastest')
['foot', 'fell', 'fastest']
>>> re.sub(r'(\b[a-z]+) \1', r'\1', 'cat in the the hat')
'cat in the hat'
```

When only simple capabilities are needed, string methods are preferred because they are easier to read and debug:

```
>>> 'tea for too'.replace('too', 'two')
'tea for two'
```

## 10.6 Mathematics

The `math` module gives access to the underlying C library functions for floating point math:

```
>>> import math
>>> math.cos(math.pi / 4.0)
0.70710678118654757
>>> math.log(1024, 2)
10.0
```

The `random` module provides tools for making random selections:

```

>>> import random
>>> random.choice(['apple', 'pear', 'banana'])
'apple'
>>> random.sample(xrange(100), 10)    # sampling without replacement
[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]
>>> random.random()                   # random float
0.17970987693706186
>>> random.randrange(6)                # random integer chosen from range(6)
4

```

## 10.7 Internet Access

There are a number of modules for accessing the internet and processing internet protocols. Two of the simplest are `urllib2` for retrieving data from urls and `smtplib` for sending mail:

```

>>> import urllib2
>>> for line in urllib2.urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl'):
...     if 'EST' in line or 'EDT' in line: # look for Eastern Time
...         print line

```

<BR>Nov. 25, 09:43:32 PM EST

```

>>> import smtplib
>>> server = smtplib.SMTP('localhost')
>>> server.sendmail('soothsayer@example.org', 'jcaesar@example.org',
...  """To: jcaesar@example.org
...  From: soothsayer@example.org
...
...  Beware the Ides of March.
...  """)
>>> server.quit()

```

(Note that the second example needs a mailserver running on localhost.)

## 10.8 Dates and Times

The `datetime` module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient member extraction for output formatting and manipulation. The module also supports objects that are timezone aware.

```

>>> # dates are easily constructed and formatted
>>> from datetime import date
>>> now = date.today()
>>> now
datetime.date(2003, 12, 2)
>>> now.strftime("%m-%d-%y. %d %b %Y is a %A on the %d day of %B.")
'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

>>> # dates support calendar arithmetic
>>> birthday = date(1964, 7, 31)
>>> age = now - birthday

```

```
>>> age.days
14368
```

## 10.9 Data Compression

Common data archiving and compression formats are directly supported by modules including: `zlib`, `gzip`, `bz2`, `zipfile` and `tarfile`.

```
>>> import zlib
>>> s = 'witch which has which witches wrist watch'
>>> len(s)
41
>>> t = zlib.compress(s)
>>> len(t)
37
>>> zlib.decompress(t)
'witch which has which witches wrist watch'
>>> zlib.crc32(s)
226805979
```

## 10.10 Performance Measurement

Some Python users develop a deep interest in knowing the relative performance of different approaches to the same problem. Python provides a measurement tool that answers those questions immediately.

For example, it may be tempting to use the tuple packing and unpacking feature instead of the traditional approach to swapping arguments. The `timeit` module quickly demonstrates a modest performance advantage:

```
>>> from timeit import Timer
>>> Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()
0.57535828626024577
>>> Timer('a,b = b,a', 'a=1; b=2').timeit()
0.54962537085770791
```

In contrast to `timeit`'s fine level of granularity, the `profile` and `pstats` modules provide tools for identifying time critical sections in larger blocks of code.

## 10.11 Quality Control

One approach for developing high quality software is to write tests for each function as it is developed and to run those tests frequently during the development process.

The `doctest` module provides a tool for scanning a module and validating tests embedded in a program's docstrings. Test construction is as simple as cutting-and-pasting a typical call along with its results into the docstring. This improves the documentation by providing the user with an example and it allows the `doctest` module to make sure the code remains true to the documentation:

```
def average(values):
    """Computes the arithmetic mean of a list of numbers.

    >>> print average([20, 30, 70])
    40.0
```

```

"""
return sum(values, 0.0) / len(values)

```

```
import doctest
```

```
doctest.testmod() # automatically validate the embedded tests
```

The `unittest` module is not as effortless as the `doctest` module, but it allows a more comprehensive set of tests to be maintained in a separate file:

```
import unittest
```

```
class TestStatisticalFunctions(unittest.TestCase):
```

```

def test_average(self):
    self.assertEqual(average([20, 30, 70]), 40.0)
    self.assertEqual(round(average([1, 5, 7]), 1), 4.3)
    self.assertRaises(ZeroDivisionError, average, [])
    self.assertRaises(TypeError, average, 20, 30, 70)

```

```
unittest.main() # Calling from the command line invokes all tests
```

## 10.12 Batteries Included

Python has a “batteries included” philosophy. This is best seen through the sophisticated and robust capabilities of its larger packages. For example:

- The `xmlrpclib` and `SimpleXMLRPCServer` modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
- The `email` package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike `smtpplib` and `poplib` which actually send and receive messages, the `email` package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
- The `xml.dom` and `xml.sax` packages provide robust support for parsing this popular data interchange format. Likewise, the `csv` module supports direct reads and writes in a common database format. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
- Internationalization is supported by a number of modules including `gettext`, `locale`, and the `codecs` package.



# BRIEF TOUR OF THE STANDARD LIBRARY – PART II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1 Output Formatting

The `repr` module provides a version of `repr()` customized for abbreviated displays of large or deeply nested containers:

```
>>> import repr
>>> repr.repr(set('supercalifragilisticexpialidocious'))
"set(['a', 'c', 'd', 'e', 'f', 'g', ...])"
```

The `pprint` module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

```
>>> import pprint
>>> t = [[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',
...     'yellow'], 'blue']]
...
>>> pprint.pprint(t, width=30)
[[['black', 'cyan'],
   'white',
   ['green', 'red']],
 [['magenta', 'yellow'],
  'blue']]
```

The `textwrap` module formats paragraphs of text to fit a given screen width:

```
>>> import textwrap
>>> doc = """The wrap() method is just like fill() except that it returns
... a list of strings instead of one big string with newlines to separate
... the wrapped lines."""
...
>>> print textwrap.fill(doc, width=40)
```

The `wrap()` method is just like `fill()` except that it returns a list of strings

instead of one big string with newlines to separate the wrapped lines.

The `locale` module accesses a database of culture specific data formats. The `grouping` attribute of `locale`'s `format` function provides a direct way of formatting numbers with group separators:

```
>>> import locale
>>> locale.setlocale(locale.LC_ALL, 'English_United States.1252')
'English_United States.1252'
>>> conv = locale.localeconv()           # get a mapping of conventions
>>> x = 1234567.8
>>> locale.format("%d", x, grouping=True)
'1,234,567'
>>> locale.format_string("%s%.*f", (conv['currency_symbol'],
...                               conv['frac_digits'], x), grouping=True)
'$1,234,567.80'
```

## 11.2 Templating

The `string` module includes a versatile `Template` class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by `$` with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing `$$` creates a single escaped `$`:

```
>>> from string import Template
>>> t = Template('${village}folk send $$10 to $cause.')
>>> t.substitute(village='Nottingham', cause='the ditch fund')
'Nottinghamfolk send $10 to the ditch fund.'
```

The `substitute()` method raises a `KeyError` when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the `safe_substitute()` method may be more appropriate — it will leave placeholders unchanged if data is missing:

```
>>> t = Template('Return the $item to $owner.')
>>> d = dict(item='unladen swallow')
>>> t.substitute(d)
Traceback (most recent call last):
  . . .
KeyError: 'owner'
>>> t.safe_substitute(d)
'Return the unladen swallow to $owner.'
```

`Template` subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

```
>>> import time, os.path
>>> photofiles = ['img_1074.jpg', 'img_1076.jpg', 'img_1077.jpg']
>>> class BatchRename(Template):
...     delimiter = '%'
>>> fmt = raw_input('Enter rename style (%d-date %n-seqnum %f-format): ')
Enter rename style (%d-date %n-seqnum %f-format): Ashley_%n%f

>>> t = BatchRename(fmt)
>>> date = time.strftime('%d%b%y')
```

```
>>> for i, filename in enumerate(photofiles):
...     base, ext = os.path.splitext(filename)
...     newname = t.substitute(d=date, n=i, f=ext)
...     print '{0} --> {1}'.format(filename, newname)
```

```
img_1074.jpg --> Ashley_0.jpg
img_1076.jpg --> Ashley_1.jpg
img_1077.jpg --> Ashley_2.jpg
```

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3 Working with Binary Data Record Layouts

The `struct` module provides `pack()` and `unpack()` functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the `zipfile` module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

```
import struct

data = open('myfile.zip', 'rb').read()
start = 0
for i in range(3):
    # show the first 3 file headers
    start += 14
    fields = struct.unpack('<IIHH', data[start:start+16])
    crc32, comp_size, uncomp_size, filenamesize, extra_size = fields

    start += 16
    filename = data[start:start+filenamesize]
    start += filenamesize
    extra = data[start:start+extra_size]
    print filename, hex(crc32), comp_size, uncomp_size

    start += extra_size + comp_size    # skip to the next header
```

## 11.4 Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level `threading` module can run tasks in background while the main program continues to run:

```
import threading, zipfile

class AsyncZip(threading.Thread):
    def __init__(self, infile, outfile):
        threading.Thread.__init__(self)
        self.infile = infile
        self.outfile = outfile
    def run(self):
```

```
f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP_DEFLATED)
f.write(self.infile)
f.close()
print 'Finished background zip of: ', self.infile

background = AsyncZip('mydata.txt', 'myarchive.zip')
background.start()
print 'The main program continues to run in foreground.'

background.join()    # Wait for the background task to finish
print 'Main program waited until background was done.'
```

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the Queue module to feed that thread with requests from other threads. Applications using Queue.Queue objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5 Logging

The logging module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to `sys.stderr`:

```
import logging
logging.debug('Debugging information')
logging.info('Informational message')
logging.warning('Warning:config file %s not found', 'server.conf')
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')
```

This produces the following output:

```
WARNING:root:Warning:config file server.conf not found
ERROR:root:Error occurred
CRITICAL:root:Critical error -- shutting down
```

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO, WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6 Weak References

Python does automatic memory management (reference counting for most objects and *garbage collection* to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The weakref module provides tools for tracking objects without creating a reference. When the object is no longer

needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

```
>>> import weakref, gc
>>> class A:
...     def __init__(self, value):
...         self.value = value
...     def __repr__(self):
...         return str(self.value)
...
>>> a = A(10)                # create a reference
>>> d = weakref.WeakValueDictionary()
>>> d['primary'] = a         # does not create a reference
>>> d['primary']           # fetch the object if it is still alive
10
>>> del a                  # remove the one reference
>>> gc.collect()          # run garbage collection right away
0
>>> d['primary']           # entry was automatically removed
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    d['primary']           # entry was automatically removed
  File "C:/python26/lib/weakref.py", line 46, in __getitem__
    o = self.data[key]()
KeyError: 'primary'
```

## 11.7 Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The `array` module provides an `array()` object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

```
>>> from array import array
>>> a = array('H', [4000, 10, 700, 22222])
>>> sum(a)
26932
>>> a[1:3]
array('H', [10, 700])
```

The `collections` module provides a `deque()` object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

```
>>> from collections import deque
>>> d = deque(["task1", "task2", "task3"])
>>> d.append("task4")
>>> print "Handling", d.popleft()
Handling task1
```

```
unsearched = deque([starting_node])
def breadth_first_search(unsearched):
    node = unsearched.popleft()
```

```
for m in gen_moves(node):
    if is_goal(m):
        return m
    unsearched.append(m)
```

In addition to alternative list implementations, the library also offers other tools such as the `bisect` module with functions for manipulating sorted lists:

```
>>> import bisect
>>> scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]
>>> bisect.insort(scores, (300, 'ruby'))
>>> scores
[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]
```

The `heapq` module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

```
>>> from heapq import heapify, heappop, heappush
>>> data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]
>>> heapify(data) # rearrange the list into heap order
>>> heappush(data, -5) # add a new entry
>>> [heappop(data) for i in range(3)] # fetch the three smallest entries
[-5, 0, 1]
```

## 11.8 Decimal Floating Point Arithmetic

The `decimal` module offers a `Decimal` datatype for decimal floating point arithmetic. Compared to the built-in `float` implementation of binary floating point, the class is especially helpful for

- financial applications and other uses which require exact decimal representation,
- control over precision,
- control over rounding to meet legal or regulatory requirements,
- tracking of significant decimal places, or
- applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

```
>>> from decimal import *
>>> x = Decimal('0.70') * Decimal('1.05')
>>> x
Decimal('0.7350')
>>> x.quantize(Decimal('0.01')) # round to nearest cent
Decimal('0.74')
>>> round(.70 * 1.05, 2) # same calculation with floats
0.73
```

The `Decimal` result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. `Decimal` reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the `Decimal` class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

```
>>> Decimal('1.00') % Decimal('.10')
Decimal('0.00')
>>> 1.00 % 0.10
0.099999999999999995

>>> sum([Decimal('0.1')]*10) == Decimal('1.0')
True
>>> sum([0.1]*10) == 1.0
False
```

The decimal module provides arithmetic with as much precision as needed:

```
>>> getcontext().prec = 36
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857')
```



## WHAT NOW?

Reading this tutorial has probably reinforced your interest in using Python — you should be eager to apply Python to solving your real-world problems. Where should you go to learn more?

This tutorial is part of Python’s documentation set. Some other documents in the set are:

- *library-index*:

You should browse through this manual, which gives complete (though terse) reference material about types, functions, and the modules in the standard library. The standard Python distribution includes a *lot* of additional code. There are modules to read Unix mailboxes, retrieve documents via HTTP, generate random numbers, parse command-line options, write CGI programs, compress data, and many other tasks. Skimming through the Library Reference will give you an idea of what’s available.

- *install-index* explains how to install external modules written by other Python users.
- *reference-index*: A detailed explanation of Python’s syntax and semantics. It’s heavy reading, but is useful as a complete guide to the language itself.

More Python resources:

- <http://www.python.org>: The major Python Web site. It contains code, documentation, and pointers to Python-related pages around the Web. This Web site is mirrored in various places around the world, such as Europe, Japan, and Australia; a mirror may be faster than the main site, depending on your geographical location.
- <http://docs.python.org>: Fast access to Python’s documentation.
- <http://pypi.python.org>: The Python Package Index, previously also nicknamed the Cheese Shop, is an index of user-created Python modules that are available for download. Once you begin releasing code, you can register it here so that others can find it.
- <http://aspn.activestate.com/ASPN/Python/Cookbook/>: The Python Cookbook is a sizable collection of code examples, larger modules, and useful scripts. Particularly notable contributions are collected in a book also titled Python Cookbook (O’Reilly & Associates, ISBN 0-596-00797-3.)

For Python-related questions and problem reports, you can post to the newsgroup `comp.lang.python`, or send them to the mailing list at [python-list@python.org](mailto:python-list@python.org). The newsgroup and mailing list are gatewayed, so messages posted to one will automatically be forwarded to the other. There are around 120 postings a day (with peaks up to several hundred), asking (and answering) questions, suggesting new features, and announcing new modules. Before posting, be sure to check the list of [Frequently Asked Questions](#) (also called the FAQ), or look for it in the `Misc/` directory of the Python source distribution. Mailing list archives are available at <http://mail.python.org/pipermail/>. The FAQ answers many of the questions that come up again and again, and may already contain the solution for your problem.



# INTERACTIVE INPUT EDITING AND HISTORY SUBSTITUTION

Some versions of the Python interpreter support editing of the current input line and history substitution, similar to facilities found in the Korn shell and the GNU Bash shell. This is implemented using the [GNU Readline](#) library, which supports Emacs-style and vi-style editing. This library has its own documentation which I won't duplicate here; however, the basics are easily explained. The interactive editing and history described here are optionally available in the Unix and Cygwin versions of the interpreter.

This chapter does *not* document the editing facilities of Mark Hammond's PythonWin package or the Tk-based environment, IDLE, distributed with Python. The command line history recall which operates within DOS boxes on NT and some other DOS and Windows flavors is yet another beast.

## 13.1 Line Editing

If supported, input line editing is active whenever the interpreter prints a primary or secondary prompt. The current line can be edited using the conventional Emacs control characters. The most important of these are: C-A (Control-A) moves the cursor to the beginning of the line, C-E to the end, C-B moves it one position to the left, C-F to the right. Backspace erases the character to the left of the cursor, C-D the character to its right. C-K kills (erases) the rest of the line to the right of the cursor, C-Y yanks back the last killed string. C-underscore undoes the last change you made; it can be repeated for cumulative effect.

## 13.2 History Substitution

History substitution works as follows. All non-empty input lines issued are saved in a history buffer, and when a new prompt is given you are positioned on a new line at the bottom of this buffer. C-P moves one line up (back) in the history buffer, C-N moves one down. Any line in the history buffer can be edited; an asterisk appears in front of the prompt to mark a line as modified. Pressing the Return key passes the current line to the interpreter. C-R starts an incremental reverse search; C-S starts a forward search.

## 13.3 Key Bindings

The key bindings and some other parameters of the Readline library can be customized by placing commands in an initialization file called `~/.inputrc`. Key bindings have the form

```
key-name: function-name
```

or

```
"string": function-name
```

and options can be set with

```
set option-name value
```

For example:

```
# I prefer vi-style editing:
set editing-mode vi

# Edit using a single line:
set horizontal-scroll-mode On

# Rebind some keys:
Meta-h: backward-kill-word
"\C-u": universal-argument
"\C-x\C-r": re-read-init-file
```

Note that the default binding for Tab in Python is to insert a Tab character instead of Readline's default filename completion function. If you insist, you can override this by putting

```
Tab: complete
```

in your `~/.inputrc`. (Of course, this makes it harder to type indented continuation lines if you're accustomed to using Tab for that purpose.)

Automatic completion of variable and module names is optionally available. To enable it in the interpreter's interactive mode, add the following to your startup file: <sup>1</sup>

```
import rlcompleter, readline
readline.parse_and_bind('tab: complete')
```

This binds the Tab key to the completion function, so hitting the Tab key twice suggests completions; it looks at Python statement names, the current local variables, and the available module names. For dotted expressions such as `string.a`, it will evaluate the expression up to the final `'.'` and then suggest completions from the attributes of the resulting object. Note that this may execute application-defined code if an object with a `__getattr__()` method is part of the expression.

A more capable startup file might look like this example. Note that this deletes the names it creates once they are no longer needed; this is done since the startup file is executed in the same namespace as the interactive commands, and removing the names avoids creating side effects in the interactive environment. You may find it convenient to keep some of the imported modules, such as `os`, which turn out to be needed in most sessions with the interpreter.

```
# Add auto-completion and a stored history file of commands to your Python
# interactive interpreter. Requires Python 2.0+, readline. Autocomplete is
# bound to the Esc key by default (you can change it - see readline docs).
#
# Store the file in ~/.pystartup, and set an environment variable to point
# to it: "export PYTHONSTARTUP=~/.pystartup" in bash.
```

```
import atexit
import os
import readline
import rlcompleter
```

---

<sup>1</sup> Python will execute the contents of a file identified by the `PYTHONSTARTUP` environment variable when you start an interactive interpreter. To customize Python even for non-interactive mode, see *The Customization Modules*.

```
historyPath = os.path.expanduser("~/pyhistory")

def save_history(historyPath=historyPath):
    import readline
    readline.write_history_file(historyPath)

if os.path.exists(historyPath):
    readline.read_history_file(historyPath)

atexit.register(save_history)
del os, atexit, readline, rlcompleter, save_history, historyPath
```

## 13.4 Alternatives to the Interactive Interpreter

This facility is an enormous step forward compared to earlier versions of the interpreter; however, some wishes are left: It would be nice if the proper indentation were suggested on continuation lines (the parser knows if an indent token is required next). The completion mechanism might use the interpreter's symbol table. A command to check (or even suggest) matching parentheses, quotes, etc., would also be useful.

One alternative enhanced interactive interpreter that has been around for quite some time is [IPython](#), which features tab completion, object exploration and advanced history management. It can also be thoroughly customized and embedded into other applications. Another similar enhanced interactive environment is [bpython](#).



# FLOATING POINT ARITHMETIC: ISSUES AND LIMITATIONS

Floating-point numbers are represented in computer hardware as base 2 (binary) fractions. For example, the decimal fraction

0.125

has value  $1/10 + 2/100 + 5/1000$ , and in the same way the binary fraction

0.001

has value  $0/2 + 0/4 + 1/8$ . These two fractions have identical values, the only real difference being that the first is written in base 10 fractional notation, and the second in base 2.

Unfortunately, most decimal fractions cannot be represented exactly as binary fractions. A consequence is that, in general, the decimal floating-point numbers you enter are only approximated by the binary floating-point numbers actually stored in the machine.

The problem is easier to understand at first in base 10. Consider the fraction  $1/3$ . You can approximate that as a base 10 fraction:

0.3

or, better,

0.33

or, better,

0.333

and so on. No matter how many digits you're willing to write down, the result will never be exactly  $1/3$ , but will be an increasingly better approximation of  $1/3$ .

In the same way, no matter how many base 2 digits you're willing to use, the decimal value 0.1 cannot be represented exactly as a base 2 fraction. In base 2,  $1/10$  is the infinitely repeating fraction

0.000110011001100110011001100110011001100110011001100110011...

Stop at any finite number of bits, and you get an approximation.

On a typical machine running Python, there are 53 bits of precision available for a Python float, so the value stored internally when you enter the decimal number 0.1 is the binary fraction

0.000110011001100110011001100110011001100110011001100110011010

which is close to, but not exactly equal to,  $1/10$ .

It's easy to forget that the stored value is an approximation to the original decimal fraction, because of the way that floats are displayed at the interpreter prompt. Python only prints a decimal approximation to the true decimal value of the binary approximation stored by the machine. If Python were to print the true decimal value of the binary approximation stored for 0.1, it would have to display

```
>>> 0.1
0.1000000000000000055511151231257827021181583404541015625
```

That is more digits than most people find useful, so Python keeps the number of digits manageable by displaying a rounded value instead

```
>>> 0.1
0.1
```

It's important to realize that this is, in a real sense, an illusion: the value in the machine is not exactly 1/10, you're simply rounding the *display* of the true machine value. This fact becomes apparent as soon as you try to do arithmetic with these values

```
>>> 0.1 + 0.2
0.30000000000000004
```

Note that this is in the very nature of binary floating-point: this is not a bug in Python, and it is not a bug in your code either. You'll see the same kind of thing in all languages that support your hardware's floating-point arithmetic (although some languages may not *display* the difference by default, or in all output modes).

Other surprises follow from this one. For example, if you try to round the value 2.675 to two decimal places, you get this

```
>>> round(2.675, 2)
2.67
```

The documentation for the built-in `round()` function says that it rounds to the nearest value, rounding ties away from zero. Since the decimal fraction 2.675 is exactly halfway between 2.67 and 2.68, you might expect the result here to be (a binary approximation to) 2.68. It's not, because when the decimal string 2.675 is converted to a binary floating-point number, it's again replaced with a binary approximation, whose exact value is

```
2.67499999999999982236431605997495353221893310546875
```

Since this approximation is slightly closer to 2.67 than to 2.68, it's rounded down.

If you're in a situation where you care which way your decimal half-way-cases are rounded, you should consider using the `decimal` module. Incidentally, the `decimal` module also provides a nice way to "see" the exact value that's stored in any particular Python float

```
>>> from decimal import Decimal
>>> Decimal(2.675)
Decimal('2.67499999999999982236431605997495353221893310546875')
```

Another consequence is that since 0.1 is not exactly 1/10, summing ten values of 0.1 may not yield exactly 1.0, either:

```
>>> sum = 0.0
>>> for i in range(10):
...     sum += 0.1
...
>>> sum
0.9999999999999999
```

Binary floating-point arithmetic holds many surprises like this. The problem with "0.1" is explained in precise detail below, in the "Representation Error" section. See [The Perils of Floating Point](#) for a more complete account of other common surprises.

As that says near the end, “there are no easy answers.” Still, don’t be unduly wary of floating-point! The errors in Python float operations are inherited from the floating-point hardware, and on most machines are on the order of no more than 1 part in  $2^{53}$  per operation. That’s more than adequate for most tasks, but you do need to keep in mind that it’s not decimal arithmetic, and that every float operation can suffer a new rounding error.

While pathological cases do exist, for most casual use of floating-point arithmetic you’ll see the result you expect in the end if you simply round the display of your final results to the number of decimal digits you expect. For fine control over how a float is displayed see the `str.format()` method’s format specifiers in *formatstrings*.

## 14.1 Representation Error

This section explains the “0.1” example in detail, and shows how you can perform an exact analysis of cases like this yourself. Basic familiarity with binary floating-point representation is assumed.

*Representation error* refers to the fact that some (most, actually) decimal fractions cannot be represented exactly as binary (base 2) fractions. This is the chief reason why Python (or Perl, C, C++, Java, Fortran, and many others) often won’t display the exact decimal number you expect:

```
>>> 0.1 + 0.2
0.30000000000000004
```

Why is that?  $1/10$  and  $2/10$  are not exactly representable as a binary fraction. Almost all machines today (July 2010) use IEEE-754 floating point arithmetic, and almost all platforms map Python floats to IEEE-754 “double precision”. 754 doubles contain 53 bits of precision, so on input the computer strives to convert 0.1 to the closest fraction it can of the form  $J/2^N$  where  $J$  is an integer containing exactly 53 bits. Rewriting

$$1 / 10 \approx J / (2^N)$$

as

$$J \approx 2^N / 10$$

and recalling that  $J$  has exactly 53 bits (is  $\geq 2^{52}$  but  $< 2^{53}$ ), the best value for  $N$  is 56:

```
>>> 2**52
4503599627370496
>>> 2**53
9007199254740992
>>> 2**56/10
7205759403792793
```

That is, 56 is the only value for  $N$  that leaves  $J$  with exactly 53 bits. The best possible value for  $J$  is then that quotient rounded:

```
>>> q, r = divmod(2**56, 10)
>>> r
6
```

Since the remainder is more than half of 10, the best approximation is obtained by rounding up:

```
>>> q+1
7205759403792794
```

Therefore the best possible approximation to  $1/10$  in 754 double precision is that over  $2^{56}$ , or

```
7205759403792794 / 72057594037927936
```

Note that since we rounded up, this is actually a little bit larger than  $1/10$ ; if we had not rounded up, the quotient would have been a little bit smaller than  $1/10$ . But in no case can it be *exactly*  $1/10$ !

So the computer never “sees” 1/10: what it sees is the exact fraction given above, the best 754 double approximation it can get:

```
>>> .1 * 2**56
7205759403792794.0
```

If we multiply that fraction by 10\*\*30, we can see the (truncated) value of its 30 most significant decimal digits:

```
>>> 7205759403792794 * 10**30 // 2**56
100000000000000000005551115123125L
```

meaning that the exact number stored in the computer is approximately equal to the decimal value 0.100000000000000000005551115123125. In versions prior to Python 2.7 and Python 3.1, Python rounded this value to 17 significant digits, giving ‘0.10000000000000001’. In current versions, Python displays a value based on the shortest decimal fraction that rounds correctly back to the true binary value, resulting simply in ‘0.1’.

---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**...** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

---

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Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

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- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
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It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

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Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

Continued on next page

**Table C.1 – continued from previous page**

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

---

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

```
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```

```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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### C.3.4 MD5 message digest algorithm

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
(section A.5) but excluding the rest of Appendix A. It does not include
any code or documentation that is identified in the RFC as being
copyrighted.
```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
references to Ghostscript; clarified derivation from RFC 1321;
now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

### **C.3.5 Asynchronous socket services**

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Author: Zooko O'Whielacronx
http://zooko.com/
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```

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Author: Andrew Dalke
```

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### C.3.8 UUencode and UUdecode functions

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Modified by Jack Jansen, CWI, July 1995:

- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

### **C.3.9 XML Remote Procedure Calls**

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### C.3.12 strtod and dtoa

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# Python Setup and Usage

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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This part of the documentation is devoted to general information on the setup of the Python environment on different platform, the invocation of the interpreter and things that make working with Python easier.



# COMMAND LINE AND ENVIRONMENT

The CPython interpreter scans the command line and the environment for various settings.

**CPython implementation detail:** Other implementations' command line schemes may differ. See *implementations* for further resources.

## 1.1 Command line

When invoking Python, you may specify any of these options:

```
python [-BdEiOQsRStuUvVWxX3?] [-c command | -m module-name | script | - ] [args]
```

The most common use case is, of course, a simple invocation of a script:

```
python myscript.py
```

### 1.1.1 Interface options

The interpreter interface resembles that of the UNIX shell, but provides some additional methods of invocation:

- When called with standard input connected to a tty device, it prompts for commands and executes them until an EOF (an end-of-file character, you can produce that with *Ctrl-D* on UNIX or *Ctrl-Z, Enter* on Windows) is read.
- When called with a file name argument or with a file as standard input, it reads and executes a script from that file.
- When called with a directory name argument, it reads and executes an appropriately named script from that directory.
- When called with `-c command`, it executes the Python statement(s) given as *command*. Here *command* may contain multiple statements separated by newlines. Leading whitespace is significant in Python statements!
- When called with `-m module-name`, the given module is located on the Python module path and executed as a script.

In non-interactive mode, the entire input is parsed before it is executed.

An interface option terminates the list of options consumed by the interpreter, all consecutive arguments will end up in `sys.argv` – note that the first element, subscript zero (`sys.argv[0]`), is a string reflecting the program's source.

**-c** <command>

Execute the Python code in *command*. *command* can be one or more statements separated by newlines, with significant leading whitespace as in normal module code.

If this option is given, the first element of `sys.argv` will be `"-c"` and the current directory will be added to the start of `sys.path` (allowing modules in that directory to be imported as top level modules).

**-m** <module-name>

Search `sys.path` for the named module and execute its contents as the `__main__` module.

Since the argument is a *module* name, you must not give a file extension (`.py`). The `module-name` should be a valid Python module name, but the implementation may not always enforce this (e.g. it may allow you to use a name that includes a hyphen).

Package names are also permitted. When a package name is supplied instead of a normal module, the interpreter will execute `<pkg>.__main__` as the main module. This behaviour is deliberately similar to the handling of directories and zipfiles that are passed to the interpreter as the script argument.

---

**Note:** This option cannot be used with built-in modules and extension modules written in C, since they do not have Python module files. However, it can still be used for precompiled modules, even if the original source file is not available.

---

If this option is given, the first element of `sys.argv` will be the full path to the module file. As with the `-c` option, the current directory will be added to the start of `sys.path`.

Many standard library modules contain code that is invoked on their execution as a script. An example is the `timeit` module:

```
python -mtimeit -s 'setup here' 'benchmarked code here'
python -mtimeit -h # for details
```

**See Also:**

`runpy.run_module()` Equivalent functionality directly available to Python code

**PEP 338** – Executing modules as scripts

New in version 2.4.Changed in version 2.5: The named module can now be located inside a package.Changed in version 2.7: Supply the package name to run a `__main__` submodule. `sys.argv[0]` is now set to `"-m"` while searching for the module (it was previously incorrectly set to `"-c"`)

-

Read commands from standard input (`sys.stdin`). If standard input is a terminal, `-i` is implied.

If this option is given, the first element of `sys.argv` will be `"-"` and the current directory will be added to the start of `sys.path`.

**<script>**

Execute the Python code contained in *script*, which must be a filesystem path (absolute or relative) referring to either a Python file, a directory containing a `__main__.py` file, or a zipfile containing a `__main__.py` file.

If this option is given, the first element of `sys.argv` will be the script name as given on the command line.

If the script name refers directly to a Python file, the directory containing that file is added to the start of `sys.path`, and the file is executed as the `__main__` module.

If the script name refers to a directory or zipfile, the script name is added to the start of `sys.path` and the `__main__.py` file in that location is executed as the `__main__` module. Changed in version 2.5: Directories and zipfiles containing a `__main__.py` file at the top level are now considered valid Python scripts.

If no interface option is given, `-i` is implied, `sys.argv[0]` is an empty string (`" "`) and the current directory will be added to the start of `sys.path`.

**See Also:**

*tut-invoking*

## 1.1.2 Generic options

**-?****-h****-help**

Print a short description of all command line options. Changed in version 2.5: The `--help` variant.

**-V****-version**

Print the Python version number and exit. Example output could be:

```
Python 2.5.1
```

Changed in version 2.5: The `--version` variant.

## 1.1.3 Miscellaneous options

**-B**

If given, Python won't try to write `.pyc` or `.pyo` files on the import of source modules. See also `PYTHONDONTWRITEBYTECODE`. New in version 2.6.

**-d**

Turn on parser debugging output (for wizards only, depending on compilation options). See also `PYTHONDEBUG`.

**-E**

Ignore all `PYTHON*` environment variables, e.g.

`PYTHONPATH` and `PYTHONHOME`, that might be set. New in version 2.2.

**-i**

When a script is passed as first argument or the `-c` option is used, enter interactive mode after executing the script or the command, even when `sys.stdin` does not appear to be a terminal. The

`PYTHONSTARTUP` file is not read.

This can be useful to inspect global variables or a stack trace when a script raises an exception. See also `PYTHONINSPECT`.

**-O**

Turn on basic optimizations. This changes the filename extension for compiled (*bytecode*) files from `.pyc` to `.pyo`. See also

`PYTHONOPTIMIZE`.

**-OO**

Discard docstrings in addition to the `-O` optimizations.

**-Q** <arg>

Division control. The argument must be one of the following:

**old** division of `int/int` and `long/long` return an `int` or `long` (*default*)

**new** new division semantics, i.e. division of `int/int` and `long/long` returns a `float`

**warn** old division semantics with a warning for `int/int` and `long/long`

**warnall** old division semantics with a warning for all uses of the division operator

### See Also:

`Tools/scripts/fixdiv.py` for a use of `warnall`

**PEP 238** – Changing the division operator

### -R

Turn on hash randomization, so that the `__hash__()` values of `str`, `bytes` and `datetime` objects are “salted” with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

This is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict construction,  $O(n^2)$  complexity. See <http://www.ocert.org/advisories/ocert-2011-003.html> for details.

Changing hash values affects the order in which keys are retrieved from a dict. Although Python has never made guarantees about this ordering (and it typically varies between 32-bit and 64-bit builds), enough real-world code implicitly relies on this non-guaranteed behavior that the randomization is disabled by default.

See also `PYTHONHASHSEED`. New in version 2.6.8.

### -s

Don't add the user `site-packages` directory to `sys.path`. New in version 2.6.

### See Also:

**PEP 370** – Per user site-packages directory

### -S

Disable the import of the module `site` and the site-dependent manipulations of `sys.path` that it entails.

### -t

Issue a warning when a source file mixes tabs and spaces for indentation in a way that makes it depend on the worth of a tab expressed in spaces. Issue an error when the option is given twice (`-tt`).

### -u

Force `stdin`, `stdout` and `stderr` to be totally unbuffered. On systems where it matters, also put `stdin`, `stdout` and `stderr` in binary mode.

Note that there is internal buffering in `file.readlines()` and *bltin-file-objects* (for `line` in `sys.stdin`) which is not influenced by this option. To work around this, you will want to use `file.readline()` inside a `while 1: loop`.

See also `PYTHONUNBUFFERED`.

### -v

Print a message each time a module is initialized, showing the place (filename or built-in module) from which it is loaded. When given twice (`-vv`), print a message for each file that is checked for when searching for a module. Also provides information on module cleanup at exit. See also `PYTHONVERBOSE`.

### -W arg

Warning control. Python's warning machinery by default prints warning messages to `sys.stderr`. A typical warning message has the following form:

```
file:line: category: message
```

By default, each warning is printed once for each source line where it occurs. This option controls how often warnings are printed.

Multiple `-W` options may be given; when a warning matches more than one option, the action for the last matching option is performed. Invalid `-W` options are ignored (though, a warning message is printed about invalid options when the first warning is issued).

Starting from Python 2.7, `DeprecationWarning` and its descendants are ignored by default. The `-Wd` option can be used to re-enable them.

Warnings can also be controlled from within a Python program using the `warnings` module.

The simplest form of argument is one of the following action strings (or a unique abbreviation) by themselves:

**ignore** Ignore all warnings.

**default** Explicitly request the default behavior (printing each warning once per source line).

**all** Print a warning each time it occurs (this may generate many messages if a warning is triggered repeatedly for the same source line, such as inside a loop).

**module** Print each warning only the first time it occurs in each module.

**once** Print each warning only the first time it occurs in the program.

**error** Raise an exception instead of printing a warning message.

The full form of argument is:

```
action:message:category:module:line
```

Here, *action* is as explained above but only applies to messages that match the remaining fields. Empty fields match all values; trailing empty fields may be omitted. The *message* field matches the start of the warning message printed; this match is case-insensitive. The *category* field matches the warning category. This must be a class name; the match tests whether the actual warning category of the message is a subclass of the specified warning category. The full class name must be given. The *module* field matches the (fully-qualified) module name; this match is case-sensitive. The *line* field matches the line number, where zero matches all line numbers and is thus equivalent to an omitted line number.

**See Also:**

`warnings` – the warnings module

**PEP 230** – Warning framework

`PYTHONWARNINGS`

**-x**

Skip the first line of the source, allowing use of non-Unix forms of `#!cmd`. This is intended for a DOS specific hack only.

---

**Note:** The line numbers in error messages will be off by one.

---

**-3**

Warn about Python 3.x incompatibilities which cannot be fixed trivially by *2to3*. Among these are:

- `dict.has_key()`
- `apply()`
- `callable()`
- `coerce()`
- `execfile()`
- `reduce()`
- `reload()`

Using these will emit a `DeprecationWarning`. New in version 2.6.

### 1.1.4 Options you shouldn't use

**-J**

Reserved for use by *Jython*.

**-U**

Turns all string literals into unicodes globally. Do not be tempted to use this option as it will probably break your world. It also produces `.pyc` files with a different magic number than normal. Instead, you can enable unicode literals on a per-module basis by using:

```
from __future__ import unicode_literals
```

at the top of the file. See `__future__` for details.

**-X**

Reserved for alternative implementations of Python to use for their own purposes.

## 1.2 Environment variables

These environment variables influence Python's behavior.

### **PYTHONHOME**

Change the location of the standard Python libraries. By default, the libraries are searched in `prefix/lib/pythonversion` and `exec_prefix/lib/pythonversion`, where `prefix` and `exec_prefix` are installation-dependent directories, both defaulting to `/usr/local`.

When `PYTHONHOME` is set to a single directory, its value replaces both `prefix` and `exec_prefix`. To specify different values for these, set `PYTHONHOME` to `prefix:exec_prefix`.

### **PYTHONPATH**

Augment the default search path for module files. The format is the same as the shell's `PATH`: one or more directory pathnames separated by `os.pathsep` (e.g. colons on Unix or semicolons on Windows). Non-existent directories are silently ignored.

In addition to normal directories, individual `PYTHONPATH` entries may refer to zipfiles containing pure Python modules (in either source or compiled form). Extension modules cannot be imported from zipfiles.

The default search path is installation dependent, but generally begins with `prefix/lib/pythonversion` (see `PYTHONHOME` above). It is *always* appended to `PYTHONPATH`.

An additional directory will be inserted in the search path in front of

`PYTHONPATH` as described above under *Interface options*. The search path can be manipulated from within a Python program as the variable `sys.path`.

### **PYTHONSTARTUP**

If this is the name of a readable file, the Python commands in that file are executed before the first prompt is displayed in interactive mode. The file is executed in the same namespace where interactive commands are executed so that objects defined or imported in it can be used without qualification in the interactive session. You can also change the prompts `sys.ps1` and `sys.ps2` in this file.

### **PYTHONY2K**

Set this to a non-empty string to cause the `time` module to require dates specified as strings to include 4-digit years, otherwise 2-digit years are converted based on rules described in the `time` module documentation.

### **PYTHONOPTIMIZE**

If this is set to a non-empty string it is equivalent to specifying the `-O` option. If set to an integer, it is equivalent to specifying `-O` multiple times.

**PYTHONDEBUG**

If this is set to a non-empty string it is equivalent to specifying the `-d` option. If set to an integer, it is equivalent to specifying `-d` multiple times.

**PYTHONINSPECT**

If this is set to a non-empty string it is equivalent to specifying the `-i` option.

This variable can also be modified by Python code using `os.environ` to force inspect mode on program termination.

**PYTHONUNBUFFERED**

If this is set to a non-empty string it is equivalent to specifying the `-u` option.

**PYTHONVERBOSE**

If this is set to a non-empty string it is equivalent to specifying the `-v` option. If set to an integer, it is equivalent to specifying `-v` multiple times.

**PYTHONCASEOK**

If this is set, Python ignores case in `import` statements. This only works on Windows, OS X, OS/2, and RiscOS.

**PYTHONDONTWRITEBYTECODE**

If this is set, Python won't try to write `.pyc` or `.pyo` files on the import of source modules. This is equivalent to specifying the `-B` option. New in version 2.6.

**PYTHONHASHSEED**

If this variable is set to `random`, the effect is the same as specifying the `-R` option: a random value is used to seed the hashes of `str`, `bytes` and `datetime` objects.

If `PYTHONHASHSEED` is set to an integer value, it is used as a fixed seed for generating the `hash()` of the types covered by the hash randomization.

Its purpose is to allow repeatable hashing, such as for selftests for the interpreter itself, or to allow a cluster of python processes to share hash values.

The integer must be a decimal number in the range `[0,4294967295]`. Specifying the value `0` will lead to the same hash values as when hash randomization is disabled. New in version 2.6.8.

**PYTHONIOENCODING**

Overrides the encoding used for `stdin/stdout/stderr`, in the syntax `encodingname:errorhandler`. The `:errorhandler` part is optional and has the same meaning as in `str.encode()`. New in version 2.6.

**PYTHONNOUSERSITE**

If this is set, Python won't add the user `site-packages` directory to `sys.path`. New in version 2.6.

**See Also:**

**PEP 370** – Per user site-packages directory

**PYTHONUSERBASE**

Defines the user base directory, which is used to compute the path of the user `site-packages` directory and *Distutils installation paths* for `python setup.py install --user`. New in version 2.6.

**See Also:**

**PEP 370** – Per user site-packages directory

**PYTHONEXECUTABLE**

If this environment variable is set, `sys.argv[0]` will be set to its value instead of the value got through the C runtime. Only works on Mac OS X.

### **PYTHONWARNINGS**

This is equivalent to the `-W` option. If set to a comma separated string, it is equivalent to specifying `-W` multiple times.

### **1.2.1 Debug-mode variables**

Setting these variables only has an effect in a debug build of Python, that is, if Python was configured with the `--with-pydebug` build option.

#### **PYTHONTHREADDEBUG**

If set, Python will print threading debug info. Changed in version 2.6: Previously, this variable was called `THREADDEBUG`.

#### **PYTHONDUMPREFS**

If set, Python will dump objects and reference counts still alive after shutting down the interpreter.

#### **PYTHONMALLOCSTATS**

If set, Python will print memory allocation statistics every time a new object arena is created, and on shutdown.

# USING PYTHON ON UNIX PLATFORMS

## 2.1 Getting and installing the latest version of Python

### 2.1.1 On Linux

Python comes preinstalled on most Linux distributions, and is available as a package on all others. However there are certain features you might want to use that are not available on your distro's package. You can easily compile the latest version of Python from source.

In the event that Python doesn't come preinstalled and isn't in the repositories as well, you can easily make packages for your own distro. Have a look at the following links:

**See Also:**

<http://www.debian.org/doc/manuals/maint-guide/first.en.html> for Debian users

<http://linuxmafia.com/pub/linux/suse-linux-internals/chapter35.html> for OpenSuse users

[http://docs.fedoraproject.org/en-US/Fedora\\_Draft\\_Documentation/0.1/html/RPM\\_Guide/ch-creating-rpms.html](http://docs.fedoraproject.org/en-US/Fedora_Draft_Documentation/0.1/html/RPM_Guide/ch-creating-rpms.html)  
for Fedora users

<http://www.slackbook.org/html/package-management-making-packages.html> for Slackware users

### 2.1.2 On FreeBSD and OpenBSD

- FreeBSD users, to add the package use:

```
pkg_add -r python
```

- OpenBSD users use:

```
pkg_add ftp://ftp.openbsd.org/pub/OpenBSD/4.2/packages/<insert your architecture here>
```

For example i386 users get the 2.5.1 version of Python using:

```
pkg_add ftp://ftp.openbsd.org/pub/OpenBSD/4.2/packages/i386/python-2.5.1p2.tgz
```

### 2.1.3 On OpenSolaris

To install the newest Python versions on OpenSolaris, install `blastwave` and type `pkg_get -i python` at the prompt.

## 2.2 Building Python

If you want to compile CPython yourself, first thing you should do is get the [source](#). You can download either the latest release's source or just grab a fresh [clone](#). (If you want to contribute patches, you will need a clone.)

The build process consists in the usual

```
./configure
make
make install
```

invocations. Configuration options and caveats for specific Unix platforms are extensively documented in the [README](#) file in the root of the Python source tree.

**Warning:** `make install` can overwrite or masquerade the `python` binary. `make altinstall` is therefore recommended instead of `make install` since it only installs `exec_prefix/bin/pythonversion`.

## 2.3 Python-related paths and files

These are subject to difference depending on local installation conventions;

`prefix` (`${prefix}`) and `exec_prefix` (`${exec_prefix}`) are installation-dependent and should be interpreted as for GNU software; they may be the same.

For example, on most Linux systems, the default for both is `/usr`.

File/directory	Meaning
<code>exec_prefix/bin/python</code>	Recommended location of the interpreter.
<code>prefix/lib/pythonversion</code> , <code>exec_prefix/lib/pythonversion</code>	Recommended locations of the directories containing the standard modules.
<code>prefix/include/pythonversion</code> , <code>exec_prefix/include/pythonversion</code>	Recommended locations of the directories containing the include files needed for developing Python extensions and embedding the interpreter.
<code>~/.pythonrc.py</code>	User-specific initialization file loaded by the user module; not used by default or by most applications.

## 2.4 Miscellaneous

To easily use Python scripts on Unix, you need to make them executable, e.g. with

```
$ chmod +x script
```

and put an appropriate Shebang line at the top of the script. A good choice is usually

```
#!/usr/bin/env python
```

which searches for the Python interpreter in the whole `PATH`. However, some Unices may not have the `env` command, so you may need to hardcode `/usr/bin/python` as the interpreter path.

To use shell commands in your Python scripts, look at the `subprocess` module.

## 2.5 Editors

Vim and Emacs are excellent editors which support Python very well. For more information on how to code in Python in these editors, look at:

- [http://www.vim.org/scripts/script.php?script\\_id=790](http://www.vim.org/scripts/script.php?script_id=790)
- <http://sourceforge.net/projects/python-mode>

Geany is an excellent IDE with support for a lot of languages. For more information, read: <http://www.geany.org/>

Komodo edit is another extremely good IDE. It also has support for a lot of languages. For more information, read: <http://www.activestate.com/store/productdetail.aspx?prdGuid=20f4ed15-6684-4118-a78b-d37ff4058c5f>



# USING PYTHON ON WINDOWS

This document aims to give an overview of Windows-specific behaviour you should know about when using Python on Microsoft Windows.

## 3.1 Installing Python

Unlike most Unix systems and services, Windows does not require Python natively and thus does not pre-install a version of Python. However, the CPython team has compiled Windows installers (MSI packages) with every release for many years.

With ongoing development of Python, some platforms that used to be supported earlier are no longer supported (due to the lack of users or developers). Check [PEP 11](#) for details on all unsupported platforms.

- DOS and Windows 3.x are deprecated since Python 2.0 and code specific to these systems was removed in Python 2.1.
- Up to 2.5, Python was still compatible with Windows 95, 98 and ME (but already raised a deprecation warning on installation). For Python 2.6 (and all following releases), this support was dropped and new releases are just expected to work on the Windows NT family.
- Windows CE is still supported.
- The [Cygwin](#) installer offers to install the [Python interpreter](#) as well; it is located under “Interpreters.” (cf. [Cygwin package source](#), [Maintainer releases](#))

See [Python for Windows \(and DOS\)](#) for detailed information about platforms with precompiled installers.

### See Also:

[Python on XP](#) “7 Minutes to “Hello World!”” by Richard Dooling, 2006

[Installing on Windows](#) in “[Dive into Python: Python from novice to pro](#)” by Mark Pilgrim, 2004, ISBN 1-59059-356-1

[For Windows users](#) in “Installing Python” in “[A Byte of Python](#)” by Swaroop C H, 2003

## 3.2 Alternative bundles

Besides the standard CPython distribution, there are modified packages including additional functionality. The following is a list of popular versions and their key features:

[ActivePython](#) Installer with multi-platform compatibility, documentation, PyWin32

**Enthought Python Distribution** Popular modules (such as PyWin32) with their respective documentation, tool suite for building extensible Python applications

Notice that these packages are likely to install *older* versions of Python.

## 3.3 Configuring Python

In order to run Python flawlessly, you might have to change certain environment settings in Windows.

### 3.3.1 Excursus: Setting environment variables

Windows has a built-in dialog for changing environment variables (following guide applies to XP classical view): Right-click the icon for your machine (usually located on your Desktop and called “My Computer”) and choose *Properties* there. Then, open the *Advanced* tab and click the *Environment Variables* button.

In short, your path is:

*My Computer* → *Properties* → *Advanced* → *Environment Variables*

In this dialog, you can add or modify User and System variables. To change System variables, you need non-restricted access to your machine (i.e. Administrator rights).

Another way of adding variables to your environment is using the **set** command:

```
set PYTHONPATH=%PYTHONPATH%;C:\My_python_lib
```

To make this setting permanent, you could add the corresponding command line to your `autoexec.bat`. **msconfig** is a graphical interface to this file.

Viewing environment variables can also be done more straight-forward: The command prompt will expand strings wrapped into percent signs automatically:

```
echo %PATH%
```

Consult **set /?** for details on this behaviour.

#### See Also:

<http://support.microsoft.com/kb/100843> Environment variables in Windows NT

<http://support.microsoft.com/kb/310519> How To Manage Environment Variables in Windows XP

<http://www.chem.gla.ac.uk/~louis/software/faq/q1.html> Setting Environment variables, Louis J. Farrugia

### 3.3.2 Finding the Python executable

Besides using the automatically created start menu entry for the Python interpreter, you might want to start Python in the DOS prompt. To make this work, you need to set your `%PATH%` environment variable to include the directory of your Python distribution, delimited by a semicolon from other entries. An example variable could look like this (assuming the first two entries are Windows’ default):

```
C:\WINDOWS\system32;C:\WINDOWS;C:\Python25
```

Typing **python** on your command prompt will now fire up the Python interpreter. Thus, you can also execute your scripts with command line options, see *Command line* documentation.

### 3.3.3 Finding modules

Python usually stores its library (and thereby your site-packages folder) in the installation directory. So, if you had installed Python to `C:\Python\`, the default library would reside in `C:\Python\Lib\` and third-party modules should be stored in `C:\Python\Lib\site-packages\`.

This is how `sys.path` is populated on Windows:

- An empty entry is added at the start, which corresponds to the current directory.
- If the environment variable `PYTHONPATH` exists, as described in *Environment variables*, its entries are added next. Note that on Windows, paths in this variable must be separated by semicolons, to distinguish them from the colon used in drive identifiers (`C:\` etc.).
- Additional “application paths” can be added in the registry as subkeys of `\SOFTWARE\Python\PythonCore\version\PythonPath` under both the `HKEY_CURRENT_USER` and `HKEY_LOCAL_MACHINE` hives. Subkeys which have semicolon-delimited path strings as their default value will cause each path to be added to `sys.path`. (Note that all known installers only use `HKLM`, so `HKCU` is typically empty.)
- If the environment variable `PYTHONHOME` is set, it is assumed as “Python Home”. Otherwise, the path of the main Python executable is used to locate a “landmark file” (`Lib\os.py`) to deduce the “Python Home”. If a Python home is found, the relevant sub-directories added to `sys.path` (`Lib`, `plat-win`, etc) are based on that folder. Otherwise, the core Python path is constructed from the `PythonPath` stored in the registry.
- If the Python Home cannot be located, no `PYTHONPATH` is specified in the environment, and no registry entries can be found, a default path with relative entries is used (e.g. `.\Lib;.\plat-win`, etc).

The end result of all this is:

- When running `python.exe`, or any other `.exe` in the main Python directory (either an installed version, or directly from the `PCbuild` directory), the core path is deduced, and the core paths in the registry are ignored. Other “application paths” in the registry are always read.
- When Python is hosted in another `.exe` (different directory, embedded via COM, etc), the “Python Home” will not be deduced, so the core path from the registry is used. Other “application paths” in the registry are always read.
- If Python can’t find its home and there is no registry (eg, frozen `.exe`, some very strange installation setup) you get a path with some default, but relative, paths.

### 3.3.4 Executing scripts

Python scripts (files with the extension `.py`) will be executed by **python.exe** by default. This executable opens a terminal, which stays open even if the program uses a GUI. If you do not want this to happen, use the extension `.pyw` which will cause the script to be executed by **pythonw.exe** by default (both executables are located in the top-level of your Python installation directory). This suppresses the terminal window on startup.

You can also make all `.py` scripts execute with **pythonw.exe**, setting this through the usual facilities, for example (might require administrative rights):

1. Launch a command prompt.
2. Associate the correct file group with `.py` scripts:

```
assoc .py=Python.File
```

3. Redirect all Python files to the new executable:

```
ftype Python.File=C:\Path\to\pythonw.exe "%1" %*
```

## 3.4 Additional modules

Even though Python aims to be portable among all platforms, there are features that are unique to Windows. A couple of modules, both in the standard library and external, and snippets exist to use these features.

The Windows-specific standard modules are documented in *mswin-specific-services*.

### 3.4.1 PyWin32

The *PyWin32* module by Mark Hammond is a collection of modules for advanced Windows-specific support. This includes utilities for:

- [Component Object Model \(COM\)](#)
- Win32 API calls
- Registry
- Event log
- [Microsoft Foundation Classes \(MFC\)](#) user interfaces

*PythonWin* is a sample MFC application shipped with *PyWin32*. It is an embeddable IDE with a built-in debugger.

**See Also:**

[Win32 How Do I...?](#) by Tim Golden

[Python and COM](#) by David and Paul Boddie

### 3.4.2 Py2exe

*Py2exe* is a *distutils* extension (see *extending-distutils*) which wraps Python scripts into executable Windows programs (\*.exe files). When you have done this, you can distribute your application without requiring your users to install Python.

### 3.4.3 WConio

Since Python's advanced terminal handling layer, *curses*, is restricted to Unix-like systems, there is a library exclusive to Windows as well: *Windows Console I/O for Python*.

*WConio* is a wrapper for Turbo-C's *CONIO.H*, used to create text user interfaces.

## 3.5 Compiling Python on Windows

If you want to compile CPython yourself, first thing you should do is get the [source](#). You can download either the latest release's source or just grab a fresh [checkout](#).

For Microsoft Visual C++, which is the compiler with which official Python releases are built, the source tree contains solutions/project files. View the *readme.txt* in their respective directories:

Directory	MSVC version	Visual Studio version
PC/VC6/	6.0	97
PC/VS7.1/	7.1	2003
PC/VS8.0/	8.0	2005
PCbuild/	9.0	2008

Note that not all of these build directories are fully supported. Read the release notes to see which compiler version the official releases for your version are built with.

Check `PC/readme.txt` for general information on the build process.

For extension modules, consult *building-on-windows*.

**See Also:**

**Python + Windows + distutils + SWIG + gcc MinGW** or “Creating Python extensions in C/C++ with SWIG and compiling them with MinGW gcc under Windows” or “Installing Python extension with distutils and without Microsoft Visual C++” by Sébastien Sauvage, 2003

**MingW – Python extensions** by Trent Apted et al, 2007

## 3.6 Other resources

**See Also:**

**Python Programming On Win32** “Help for Windows Programmers” by Mark Hammond and Andy Robinson, O’Reilly Media, 2000, ISBN 1-56592-621-8

**A Python for Windows Tutorial** by Amanda Birmingham, 2004



# USING PYTHON ON A MACINTOSH

**Author** Bob Savage <[bobsavage@mac.com](mailto:bobsavage@mac.com)>

Python on a Macintosh running Mac OS X is in principle very similar to Python on any other Unix platform, but there are a number of additional features such as the IDE and the Package Manager that are worth pointing out.

The Mac-specific modules are documented in *mac-specific-services*.

Python on Mac OS 9 or earlier can be quite different from Python on Unix or Windows, but is beyond the scope of this manual, as that platform is no longer supported, starting with Python 2.4. See <http://www.cwi.nl/~jack/macpython> for installers for the latest 2.3 release for Mac OS 9 and related documentation.

## 4.1 Getting and Installing MacPython

Mac OS X 10.5 comes with Python 2.5.1 pre-installed by Apple. If you wish, you are invited to install the most recent version of Python from the Python website (<http://www.python.org>). A current “universal binary” build of Python, which runs natively on the Mac’s new Intel and legacy PPC CPU’s, is available there.

What you get after installing is a number of things:

- A `MacPython 2.5` folder in your `Applications` folder. In here you find `IDLE`, the development environment that is a standard part of official Python distributions; `PythonLauncher`, which handles double-clicking Python scripts from the Finder; and the “Build Applet” tool, which allows you to package Python scripts as standalone applications on your system.
- A framework `/Library/Frameworks/Python.framework`, which includes the Python executable and libraries. The installer adds this location to your shell path. To uninstall MacPython, you can simply remove these three things. A symlink to the Python executable is placed in `/usr/local/bin/`.

The Apple-provided build of Python is installed in `/System/Library/Frameworks/Python.framework` and `/usr/bin/python`, respectively. You should never modify or delete these, as they are Apple-controlled and are used by Apple- or third-party software. Remember that if you choose to install a newer Python version from `python.org`, you will have two different but functional Python installations on your computer, so it will be important that your paths and usages are consistent with what you want to do.

`IDLE` includes a help menu that allows you to access Python documentation. If you are completely new to Python you should start reading the tutorial introduction in that document.

If you are familiar with Python on other Unix platforms you should read the section on running Python scripts from the Unix shell.

### 4.1.1 How to run a Python script

Your best way to get started with Python on Mac OS X is through the IDLE integrated development environment, see section *The IDE* and use the Help menu when the IDE is running.

If you want to run Python scripts from the Terminal window command line or from the Finder you first need an editor to create your script. Mac OS X comes with a number of standard Unix command line editors, **vim** and **emacs** among them. If you want a more Mac-like editor, **BBEdit** or **TextWrangler** from Bare Bones Software (see <http://www.barebones.com/products/bbedit/index.shtml>) are good choices, as is **TextMate** (see <http://macromates.com/>). Other editors include **Gvim** (<http://macvim.org>) and **Aquamacs** (<http://aquamacs.org/>).

To run your script from the Terminal window you must make sure that `/usr/local/bin` is in your shell search path.

To run your script from the Finder you have two options:

- Drag it to **PythonLauncher**
- Select **PythonLauncher** as the default application to open your script (or any `.py` script) through the finder Info window and double-click it. **PythonLauncher** has various preferences to control how your script is launched. Option-dragging allows you to change these for one invocation, or use its Preferences menu to change things globally.

### 4.1.2 Running scripts with a GUI

With older versions of Python, there is one Mac OS X quirk that you need to be aware of: programs that talk to the Aqua window manager (in other words, anything that has a GUI) need to be run in a special way. Use **pythonw** instead of **python** to start such scripts.

With Python 2.5, you can use either **python** or **pythonw**.

### 4.1.3 Configuration

Python on OS X honors all standard Unix environment variables such as

`PYTHONPATH`, but setting these variables for programs started from the Finder is non-standard as the Finder does not read your `.profile` or `.cshrc` at startup. You need to create a file `~/MacOSX/environment.plist`. See Apple's Technical Document QA1067 for details.

For more information on installation Python packages in MacPython, see section *Installing Additional Python Packages*.

## 4.2 The IDE

MacPython ships with the standard IDLE development environment. A good introduction to using IDLE can be found at [http://hkn.eecs.berkeley.edu/~dyoo/python/idle\\_intro/index.html](http://hkn.eecs.berkeley.edu/~dyoo/python/idle_intro/index.html).

## 4.3 Installing Additional Python Packages

There are several methods to install additional Python packages:

- <http://pythonmac.org/packages/> contains selected compiled packages for Python 2.5, 2.4, and 2.3.
- Packages can be installed via the standard Python distutils mode (`python setup.py install`).

- Many packages can also be installed via the **setuptools** extension.

## 4.4 GUI Programming on the Mac

There are several options for building GUI applications on the Mac with Python.

*PyObjC* is a Python binding to Apple's Objective-C/Cocoa framework, which is the foundation of most modern Mac development. Information on PyObjC is available from <http://pyobjc.sourceforge.net>.

The standard Python GUI toolkit is *Tkinter*, based on the cross-platform Tk toolkit (<http://www.tcl.tk>). An Aqua-native version of Tk is bundled with OS X by Apple, and the latest version can be downloaded and installed from <http://www.activestate.com>; it can also be built from source.

*wxPython* is another popular cross-platform GUI toolkit that runs natively on Mac OS X. Packages and documentation are available from <http://www.wxpython.org>.

*PyQt* is another popular cross-platform GUI toolkit that runs natively on Mac OS X. More information can be found at <http://www.riverbankcomputing.co.uk/software/pyqt/intro>.

## 4.5 Distributing Python Applications on the Mac

The “Build Applet” tool that is placed in the MacPython 2.5 folder is fine for packaging small Python scripts on your own machine to run as a standard Mac application. This tool, however, is not robust enough to distribute Python applications to other users.

The standard tool for deploying standalone Python applications on the Mac is **py2app**. More information on installing and using py2app can be found at <http://undefined.org/python/#py2app>.

## 4.6 Application Scripting

Python can also be used to script other Mac applications via Apple's Open Scripting Architecture (OSA); see <http://appscript.sourceforge.net>. Appscript is a high-level, user-friendly Apple event bridge that allows you to control scriptable Mac OS X applications using ordinary Python scripts. Appscript makes Python a serious alternative to Apple's own *AppleScript* language for automating your Mac. A related package, *PyOSA*, is an OSA language component for the Python scripting language, allowing Python code to be executed by any OSA-enabled application (Script Editor, Mail, iTunes, etc.). PyOSA makes Python a full peer to AppleScript.

## 4.7 Other Resources

The MacPython mailing list is an excellent support resource for Python users and developers on the Mac:

<http://www.python.org/community/sigs/current/pythonmac-sig/>

Another useful resource is the MacPython wiki:

<http://wiki.python.org/moin/MacPython>



---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**...** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

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# ABOUT THESE DOCUMENTS

These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

Continued on next page

Table C.1 – continued from previous page

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

## C.2 Terms and conditions for accessing or otherwise using Python

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.  
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)  
or init_by_array(init_key, key_length).
```

```
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```

```
Any feedback is very welcome.  
http://www.math.keio.ac.jp/matumoto/emt.html  
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
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```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
references to Ghostscript; clarified derivation from RFC 1321;
now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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Modified by Jack Jansen, CWI, July 1995:

- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

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### C.3.16 zlib

The `zlib` extension is built using an included copy of the `zlib` sources if the `zlib` version found on the system is too old to be used for the build:

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Jean-loup Gailly  
jloup@gzip.org

Mark Adler  
madler@alumni.caltech.edu

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# The Python Language Reference

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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This reference manual describes the syntax and “core semantics” of the language. It is terse, but attempts to be exact and complete. The semantics of non-essential built-in object types and of the built-in functions and modules are described in *library-index*. For an informal introduction to the language, see *tutorial-index*. For C or C++ programmers, two additional manuals exist: *extending-index* describes the high-level picture of how to write a Python extension module, and the *c-api-index* describes the interfaces available to C/C++ programmers in detail.



# INTRODUCTION

This reference manual describes the Python programming language. It is not intended as a tutorial.

While I am trying to be as precise as possible, I chose to use English rather than formal specifications for everything except syntax and lexical analysis. This should make the document more understandable to the average reader, but will leave room for ambiguities. Consequently, if you were coming from Mars and tried to re-implement Python from this document alone, you might have to guess things and in fact you would probably end up implementing quite a different language. On the other hand, if you are using Python and wonder what the precise rules about a particular area of the language are, you should definitely be able to find them here. If you would like to see a more formal definition of the language, maybe you could volunteer your time — or invent a cloning machine :-).

It is dangerous to add too many implementation details to a language reference document — the implementation may change, and other implementations of the same language may work differently. On the other hand, there is currently only one Python implementation in widespread use (although alternate implementations exist), and its particular quirks are sometimes worth being mentioned, especially where the implementation imposes additional limitations. Therefore, you'll find short “implementation notes” sprinkled throughout the text.

Every Python implementation comes with a number of built-in and standard modules. These are documented in *library-index*. A few built-in modules are mentioned when they interact in a significant way with the language definition.

## 1.1 Alternate Implementations

Though there is one Python implementation which is by far the most popular, there are some alternate implementations which are of particular interest to different audiences.

Known implementations include:

**CPython** This is the original and most-maintained implementation of Python, written in C. New language features generally appear here first.

**Jython** Python implemented in Java. This implementation can be used as a scripting language for Java applications, or can be used to create applications using the Java class libraries. It is also often used to create tests for Java libraries. More information can be found at [the Jython website](#).

**Python for .NET** This implementation actually uses the CPython implementation, but is a managed .NET application and makes .NET libraries available. It was created by Brian Lloyd. For more information, see the [Python for .NET home page](#).

**IronPython** An alternate Python for .NET. Unlike Python.NET, this is a complete Python implementation that generates IL, and compiles Python code directly to .NET assemblies. It was created by Jim Hugunin, the original creator of Jython. For more information, see [the IronPython website](#).

**PyPy** An implementation of Python written completely in Python. It supports several advanced features not found in other implementations like stackless support and a Just in Time compiler. One of the goals of the project is to encourage experimentation with the language itself by making it easier to modify the interpreter (since it is written in Python). Additional information is available on [the PyPy project's home page](#).

Each of these implementations varies in some way from the language as documented in this manual, or introduces specific information beyond what's covered in the standard Python documentation. Please refer to the implementation-specific documentation to determine what else you need to know about the specific implementation you're using.

## 1.2 Notation

The descriptions of lexical analysis and syntax use a modified BNF grammar notation. This uses the following style of definition:

```
name      ::=  lc_letter (lc_letter | "_" ) *
lc_letter ::=  "a"... "z"
```

The first line says that a name is an `lc_letter` followed by a sequence of zero or more `lc_letters` and underscores. An `lc_letter` in turn is any of the single characters 'a' through 'z'. (This rule is actually adhered to for the names defined in lexical and grammar rules in this document.)

Each rule begins with a name (which is the name defined by the rule) and `::=`. A vertical bar (`|`) is used to separate alternatives; it is the least binding operator in this notation. A star (`*`) means zero or more repetitions of the preceding item; likewise, a plus (`+`) means one or more repetitions, and a phrase enclosed in square brackets (`[ ]`) means zero or one occurrences (in other words, the enclosed phrase is optional). The `*` and `+` operators bind as tightly as possible; parentheses are used for grouping. Literal strings are enclosed in quotes. White space is only meaningful to separate tokens. Rules are normally contained on a single line; rules with many alternatives may be formatted alternatively with each line after the first beginning with a vertical bar.

In lexical definitions (as the example above), two more conventions are used: Two literal characters separated by three dots mean a choice of any single character in the given (inclusive) range of ASCII characters. A phrase between angular brackets (`< . . >`) gives an informal description of the symbol defined; e.g., this could be used to describe the notion of 'control character' if needed.

Even though the notation used is almost the same, there is a big difference between the meaning of lexical and syntactic definitions: a lexical definition operates on the individual characters of the input source, while a syntax definition operates on the stream of tokens generated by the lexical analysis. All uses of BNF in the next chapter ("Lexical Analysis") are lexical definitions; uses in subsequent chapters are syntactic definitions.

# LEXICAL ANALYSIS

A Python program is read by a *parser*. Input to the parser is a stream of *tokens*, generated by the *lexical analyzer*. This chapter describes how the lexical analyzer breaks a file into tokens.

Python uses the 7-bit ASCII character set for program text. New in version 2.3: An encoding declaration can be used to indicate that string literals and comments use an encoding different from ASCII. For compatibility with older versions, Python only warns if it finds 8-bit characters; those warnings should be corrected by either declaring an explicit encoding, or using escape sequences if those bytes are binary data, instead of characters.

The run-time character set depends on the I/O devices connected to the program but is generally a superset of ASCII.

**Future compatibility note:** It may be tempting to assume that the character set for 8-bit characters is ISO Latin-1 (an ASCII superset that covers most western languages that use the Latin alphabet), but it is possible that in the future Unicode text editors will become common. These generally use the UTF-8 encoding, which is also an ASCII superset, but with very different use for the characters with ordinals 128-255. While there is no consensus on this subject yet, it is unwise to assume either Latin-1 or UTF-8, even though the current implementation appears to favor Latin-1. This applies both to the source character set and the run-time character set.

## 2.1 Line structure

A Python program is divided into a number of *logical lines*.

### 2.1.1 Logical lines

The end of a logical line is represented by the token NEWLINE. Statements cannot cross logical line boundaries except where NEWLINE is allowed by the syntax (e.g., between statements in compound statements). A logical line is constructed from one or more *physical lines* by following the explicit or implicit *line joining* rules.

### 2.1.2 Physical lines

A physical line is a sequence of characters terminated by an end-of-line sequence. In source files, any of the standard platform line termination sequences can be used - the Unix form using ASCII LF (linefeed), the Windows form using the ASCII sequence CR LF (return followed by linefeed), or the old Macintosh form using the ASCII CR (return) character. All of these forms can be used equally, regardless of platform.

When embedding Python, source code strings should be passed to Python APIs using the standard C conventions for newline characters (the `\n` character, representing ASCII LF, is the line terminator).

### 2.1.3 Comments

A comment starts with a hash character (#) that is not part of a string literal, and ends at the end of the physical line. A comment signifies the end of the logical line unless the implicit line joining rules are invoked. Comments are ignored by the syntax; they are not tokens.

### 2.1.4 Encoding declarations

If a comment in the first or second line of the Python script matches the regular expression `coding[=:]\s*([-\\w.]+)`, this comment is processed as an encoding declaration; the first group of this expression names the encoding of the source code file. The recommended forms of this expression are

```
# -*- coding: <encoding-name> -*-
```

which is recognized also by GNU Emacs, and

```
# vim:fileencoding=<encoding-name>
```

which is recognized by Bram Moolenaar's VIM. In addition, if the first bytes of the file are the UTF-8 byte-order mark ('`\xef\xbb\xbf`'), the declared file encoding is UTF-8 (this is supported, among others, by Microsoft's **notepad**).

If an encoding is declared, the encoding name must be recognized by Python. The encoding is used for all lexical analysis, in particular to find the end of a string, and to interpret the contents of Unicode literals. String literals are converted to Unicode for syntactical analysis, then converted back to their original encoding before interpretation starts. The encoding declaration must appear on a line of its own.

### 2.1.5 Explicit line joining

Two or more physical lines may be joined into logical lines using backslash characters (\), as follows: when a physical line ends in a backslash that is not part of a string literal or comment, it is joined with the following forming a single logical line, deleting the backslash and the following end-of-line character. For example:

```
if 1900 < year < 2100 and 1 <= month <= 12 \
    and 1 <= day <= 31 and 0 <= hour < 24 \
    and 0 <= minute < 60 and 0 <= second < 60:    # Looks like a valid date
    return 1
```

A line ending in a backslash cannot carry a comment. A backslash does not continue a comment. A backslash does not continue a token except for string literals (i.e., tokens other than string literals cannot be split across physical lines using a backslash). A backslash is illegal elsewhere on a line outside a string literal.

### 2.1.6 Implicit line joining

Expressions in parentheses, square brackets or curly braces can be split over more than one physical line without using backslashes. For example:

```
month_names = ['Januari', 'Februari', 'Maart',          # These are the
               'April',   'Mei',      'Juni',          # Dutch names
               'Juli',    'Augustus', 'September',    # for the months
               'Oktober', 'November', 'December']    # of the year
```

Implicitly continued lines can carry comments. The indentation of the continuation lines is not important. Blank continuation lines are allowed. There is no NEWLINE token between implicit continuation lines. Implicitly continued lines can also occur within triple-quoted strings (see below); in that case they cannot carry comments.

## 2.1.7 Blank lines

A logical line that contains only spaces, tabs, formfeeds and possibly a comment, is ignored (i.e., no NEWLINE token is generated). During interactive input of statements, handling of a blank line may differ depending on the implementation of the read-eval-print loop. In the standard implementation, an entirely blank logical line (i.e. one containing not even whitespace or a comment) terminates a multi-line statement.

## 2.1.8 Indentation

Leading whitespace (spaces and tabs) at the beginning of a logical line is used to compute the indentation level of the line, which in turn is used to determine the grouping of statements.

First, tabs are replaced (from left to right) by one to eight spaces such that the total number of characters up to and including the replacement is a multiple of eight (this is intended to be the same rule as used by Unix). The total number of spaces preceding the first non-blank character then determines the line's indentation. Indentation cannot be split over multiple physical lines using backslashes; the whitespace up to the first backslash determines the indentation.

**Cross-platform compatibility note:** because of the nature of text editors on non-UNIX platforms, it is unwise to use a mixture of spaces and tabs for the indentation in a single source file. It should also be noted that different platforms may explicitly limit the maximum indentation level.

A formfeed character may be present at the start of the line; it will be ignored for the indentation calculations above. Formfeed characters occurring elsewhere in the leading whitespace have an undefined effect (for instance, they may reset the space count to zero).

The indentation levels of consecutive lines are used to generate INDENT and DEDENT tokens, using a stack, as follows.

Before the first line of the file is read, a single zero is pushed on the stack; this will never be popped off again. The numbers pushed on the stack will always be strictly increasing from bottom to top. At the beginning of each logical line, the line's indentation level is compared to the top of the stack. If it is equal, nothing happens. If it is larger, it is pushed on the stack, and one INDENT token is generated. If it is smaller, it *must* be one of the numbers occurring on the stack; all numbers on the stack that are larger are popped off, and for each number popped off a DEDENT token is generated. At the end of the file, a DEDENT token is generated for each number remaining on the stack that is larger than zero.

Here is an example of a correctly (though confusingly) indented piece of Python code:

```
def perm(l):
    # Compute the list of all permutations of l
    if len(l) <= 1:
        return [l]
    r = []
    for i in range(len(l)):
        s = l[:i] + l[i+1:]
        p = perm(s)
        for x in p:
            r.append(l[:i+1] + x)
    return r
```

The following example shows various indentation errors:

```
def perm(l):
for i in range(len(l)):
    s = l[:i] + l[i+1:]
    p = perm(l[:i] + l[i+1:])
    for x in p:
```

# error: first line indented  
# error: not indented  
# error: unexpected indent

```
        r.append(l[i:i+1] + x)
    return r                                # error: inconsistent dedent
```

(Actually, the first three errors are detected by the parser; only the last error is found by the lexical analyzer — the indentation of `return r` does not match a level popped off the stack.)

## 2.1.9 Whitespace between tokens

Except at the beginning of a logical line or in string literals, the whitespace characters space, tab and formfeed can be used interchangeably to separate tokens. Whitespace is needed between two tokens only if their concatenation could otherwise be interpreted as a different token (e.g., `ab` is one token, but `a b` is two tokens).

## 2.2 Other tokens

Besides `NEWLINE`, `INDENT` and `DEDENT`, the following categories of tokens exist: *identifiers*, *keywords*, *literals*, *operators*, and *delimiters*. Whitespace characters (other than line terminators, discussed earlier) are not tokens, but serve to delimit tokens. Where ambiguity exists, a token comprises the longest possible string that forms a legal token, when read from left to right.

## 2.3 Identifiers and keywords

Identifiers (also referred to as *names*) are described by the following lexical definitions:

```
identifier ::= (letter|"_") (letter | digit | "_")*
letter     ::= lowercase | uppercase
lowercase  ::= "a"... "z"
uppercase  ::= "A"... "Z"
digit      ::= "0"... "9"
```

Identifiers are unlimited in length. Case is significant.

### 2.3.1 Keywords

The following identifiers are used as reserved words, or *keywords* of the language, and cannot be used as ordinary identifiers. They must be spelled exactly as written here:

```
and      del      from      not      while
as       elif     global   or       with
assert   else     if       pass    yield
break    except   import   print
class    exec     in       raise
continue finally   is       return
def      for      lambda   try
```

Changed in version 2.4: `None` became a constant and is now recognized by the compiler as a name for the built-in object `None`. Although it is not a keyword, you cannot assign a different object to it. Changed in version 2.5: Using `as` and `with` as identifiers triggers a warning. To use them as keywords, enable the `with_statement` future feature. Changed in version 2.6: `as` and `with` are full keywords.

## 2.3.2 Reserved classes of identifiers

Certain classes of identifiers (besides keywords) have special meanings. These classes are identified by the patterns of leading and trailing underscore characters:

- `_*` Not imported by `from module import *`. The special identifier `_` is used in the interactive interpreter to store the result of the last evaluation; it is stored in the `__builtin__` module. When not in interactive mode, `_` has no special meaning and is not defined. See section *The import statement*.

---

**Note:** The name `_` is often used in conjunction with internationalization; refer to the documentation for the `gettext` module for more information on this convention.

---

- `__*` System-defined names. These names are defined by the interpreter and its implementation (including the standard library). Current system names are discussed in the *Special method names* section and elsewhere. More will likely be defined in future versions of Python. Any use of `__*` names, in any context, that does not follow explicitly documented use, is subject to breakage without warning.
- `__*` Class-private names. Names in this category, when used within the context of a class definition, are re-written to use a mangled form to help avoid name clashes between “private” attributes of base and derived classes. See section *Identifiers (Names)*.

## 2.4 Literals

Literals are notations for constant values of some built-in types.

### 2.4.1 String literals

String literals are described by the following lexical definitions:

```
stringliteral ::= [stringprefix] (shortstring | longstring)
stringprefix ::= "r" | "u" | "ur" | "R" | "U" | "UR" | "Ur" | "uR"
               | "b" | "B" | "br" | "Br" | "bR" | "BR"
shortstring  ::= ''' shortstringitem* ''' | ''' shortstringitem* '''
longstring   ::= ''' longstringitem* '''
               | """ longstringitem* """
shortstringitem ::= shortstringchar | escapeseq
longstringitem  ::= longstringchar | escapeseq
shortstringchar ::= <any source character except "\" or newline or the quote>
longstringchar  ::= <any source character except "\">
escapeseq       ::= "\" <any ASCII character>
```

One syntactic restriction not indicated by these productions is that whitespace is not allowed between the `stringprefix` and the rest of the string literal. The source character set is defined by the encoding declaration; it is ASCII if no encoding declaration is given in the source file; see section *Encoding declarations*.

In plain English: String literals can be enclosed in matching single quotes (`'`) or double quotes (`"`). They can also be enclosed in matching groups of three single or double quotes (these are generally referred to as *triple-quoted strings*). The backslash (`\`) character is used to escape characters that otherwise have a special meaning, such as newline, backslash itself, or the quote character. String literals may optionally be prefixed with a letter `'r'` or `'R'`; such strings are called *raw strings* and use different rules for interpreting backslash escape sequences. A prefix of `'u'` or `'U'` makes the string a Unicode string. Unicode strings use the Unicode character set as defined by the Unicode Consortium and ISO 10646. Some additional escape sequences, described below, are available in Unicode strings. A

prefix of 'b' or 'B' is ignored in Python 2; it indicates that the literal should become a bytes literal in Python 3 (e.g. when code is automatically converted with 2to3). A 'u' or 'b' prefix may be followed by an 'r' prefix.

In triple-quoted strings, unescaped newlines and quotes are allowed (and are retained), except that three unescaped quotes in a row terminate the string. (A “quote” is the character used to open the string, i.e. either ' or ".)

Unless an 'r' or 'R' prefix is present, escape sequences in strings are interpreted according to rules similar to those used by Standard C. The recognized escape sequences are:

Escape Sequence	Meaning	Notes
<code>\newline</code>	Ignored	
<code>\\</code>	Backslash ( <code>\</code> )	
<code>\'</code>	Single quote ( <code>'</code> )	
<code>\"</code>	Double quote ( <code>"</code> )	
<code>\a</code>	ASCII Bell (BEL)	
<code>\b</code>	ASCII Backspace (BS)	
<code>\f</code>	ASCII Formfeed (FF)	
<code>\n</code>	ASCII Linefeed (LF)	
<code>\N{name}</code>	Character named <i>name</i> in the Unicode database (Unicode only)	
<code>\r</code>	ASCII Carriage Return (CR)	
<code>\t</code>	ASCII Horizontal Tab (TAB)	
<code>\uxxxx</code>	Character with 16-bit hex value <i>xxxx</i> (Unicode only)	(1)
<code>\Uxxxxxxxx</code>	Character with 32-bit hex value <i>xxxxxxxx</i> (Unicode only)	(2)
<code>\v</code>	ASCII Vertical Tab (VT)	
<code>\ooo</code>	Character with octal value <i>ooo</i>	(3,5)
<code>\xhh</code>	Character with hex value <i>hh</i>	(4,5)

Notes:

1. Individual code units which form parts of a surrogate pair can be encoded using this escape sequence.
2. Any Unicode character can be encoded this way, but characters outside the Basic Multilingual Plane (BMP) will be encoded using a surrogate pair if Python is compiled to use 16-bit code units (the default). Individual code units which form parts of a surrogate pair can be encoded using this escape sequence.
3. As in Standard C, up to three octal digits are accepted.
4. Unlike in Standard C, exactly two hex digits are required.
5. In a string literal, hexadecimal and octal escapes denote the byte with the given value; it is not necessary that the byte encodes a character in the source character set. In a Unicode literal, these escapes denote a Unicode character with the given value.

Unlike Standard C, all unrecognized escape sequences are left in the string unchanged, i.e., *the backslash is left in the string*. (This behavior is useful when debugging: if an escape sequence is mistyped, the resulting output is more easily recognized as broken.) It is also important to note that the escape sequences marked as “(Unicode only)” in the table above fall into the category of unrecognized escapes for non-Unicode string literals.

When an 'r' or 'R' prefix is present, a character following a backslash is included in the string without change, and *all backslashes are left in the string*. For example, the string literal `r"\n"` consists of two characters: a backslash and a lowercase 'n'. String quotes can be escaped with a backslash, but the backslash remains in the string; for example, `r"\""` is a valid string literal consisting of two characters: a backslash and a double quote; `r"\` is not a valid string literal (even a raw string cannot end in an odd number of backslashes). Specifically, *a raw string cannot end in a single backslash* (since the backslash would escape the following quote character). Note also that a single backslash followed by a newline is interpreted as those two characters as part of the string, *not* as a line continuation.

When an 'r' or 'R' prefix is used in conjunction with a 'u' or 'U' prefix, then the `\uxxxx` and `\Uxxxxxxxx` escape sequences are processed while *all other backslashes are left in the string*. For example, the string literal `ur"\u0062\n"` consists of three Unicode characters: 'LATIN SMALL LETTER B', 'REVERSE SOLIDUS', and

‘LATIN SMALL LETTER N’. Backslashes can be escaped with a preceding backslash; however, both remain in the string. As a result, `\uXXXX` escape sequences are only recognized when there are an odd number of backslashes.

## 2.4.2 String literal concatenation

Multiple adjacent string literals (delimited by whitespace), possibly using different quoting conventions, are allowed, and their meaning is the same as their concatenation. Thus, `"hello" 'world'` is equivalent to `"helloworld"`. This feature can be used to reduce the number of backslashes needed, to split long strings conveniently across long lines, or even to add comments to parts of strings, for example:

```
re.compile("[A-Za-z_]"          # letter or underscore
           "[A-Za-z0-9_]*"     # letter, digit or underscore
           )
```

Note that this feature is defined at the syntactical level, but implemented at compile time. The `+` operator must be used to concatenate string expressions at run time. Also note that literal concatenation can use different quoting styles for each component (even mixing raw strings and triple quoted strings).

## 2.4.3 Numeric literals

There are four types of numeric literals: plain integers, long integers, floating point numbers, and imaginary numbers. There are no complex literals (complex numbers can be formed by adding a real number and an imaginary number).

Note that numeric literals do not include a sign; a phrase like `-1` is actually an expression composed of the unary operator `-` and the literal `1`.

## 2.4.4 Integer and long integer literals

Integer and long integer literals are described by the following lexical definitions:

```
longinteger ::= integer ("l" | "L")
integer     ::= decimalinteger | octinteger | hexinteger | bininteger
decimalinteger ::= nonzerodigit digit* | "0"
octinteger  ::= "0" ("o" | "O") octdigit+ | "0" octdigit+
hexinteger  ::= "0" ("x" | "X") hexdigit+
bininteger  ::= "0" ("b" | "B") bindigit+
nonzerodigit ::= "1"..."9"
octdigit    ::= "0"..."7"
bindigit    ::= "0" | "1"
hexdigit    ::= digit | "a"..."f" | "A"..."F"
```

Although both lower case `'l'` and upper case `'L'` are allowed as suffix for long integers, it is strongly recommended to always use `'L'`, since the letter `'l'` looks too much like the digit `'1'`.

Plain integer literals that are above the largest representable plain integer (e.g., 2147483647 when using 32-bit arithmetic) are accepted as if they were long integers instead.<sup>1</sup> There is no limit for long integer literals apart from what can be stored in available memory.

Some examples of plain integer literals (first row) and long integer literals (second and third rows):

<sup>1</sup> In versions of Python prior to 2.4, octal and hexadecimal literals in the range just above the largest representable plain integer but below the largest unsigned 32-bit number (on a machine using 32-bit arithmetic), 4294967296, were taken as the negative plain integer obtained by subtracting 4294967296 from their unsigned value.

```

7      2147483647      0177
3L    79228162514264337593543950336L  0377L  0x100000000L
      79228162514264337593543950336      0xdeadbeef

```

## 2.4.5 Floating point literals

Floating point literals are described by the following lexical definitions:

```

floatnumber ::= pointfloat | exponentfloat
pointfloat  ::= [intpart] fraction | intpart "."
exponentfloat ::= (intpart | pointfloat) exponent
intpart     ::= digit+
fraction    ::= "." digit+
exponent    ::= ("e" | "E") ["+" | "-"] digit+

```

Note that the integer and exponent parts of floating point numbers can look like octal integers, but are interpreted using radix 10. For example, `077e010` is legal, and denotes the same number as `77e10`. The allowed range of floating point literals is implementation-dependent. Some examples of floating point literals:

```
3.14    10.    .001    1e100    3.14e-10    0e0
```

Note that numeric literals do not include a sign; a phrase like `-1` is actually an expression composed of the unary operator `-` and the literal `1`.

## 2.4.6 Imaginary literals

Imaginary literals are described by the following lexical definitions:

```

imagnumber ::= (floatnumber | intpart) ("j" | "J")

```

An imaginary literal yields a complex number with a real part of 0.0. Complex numbers are represented as a pair of floating point numbers and have the same restrictions on their range. To create a complex number with a nonzero real part, add a floating point number to it, e.g., `(3+4j)`. Some examples of imaginary literals:

```
3.14j    10.j    10j    .001j    1e100j    3.14e-10j
```

## 2.5 Operators

The following tokens are operators:

```

+      -      *      **     /      //     %
<<     >>     &      |      ^      ~
<      >      <=     >=     ==     !=     <>

```

The comparison operators `<>` and `!=` are alternate spellings of the same operator. `!=` is the preferred spelling; `<>` is obsolescent.

## 2.6 Delimiters

The following tokens serve as delimiters in the grammar:

---

(	)	[	]	{	}	@
,	:	.	\	=	;	
+=	--	*=	/=	//=	%=	
&=	=	^=	>>=	<<=	**=	

The period can also occur in floating-point and imaginary literals. A sequence of three periods has a special meaning as an ellipsis in slices. The second half of the list, the augmented assignment operators, serve lexically as delimiters, but also perform an operation.

The following printing ASCII characters have special meaning as part of other tokens or are otherwise significant to the lexical analyzer:

'	"	#	\
---	---	---	---

The following printing ASCII characters are not used in Python. Their occurrence outside string literals and comments is an unconditional error:

\$	?
----	---



# DATA MODEL

## 3.1 Objects, values and types

*Objects* are Python’s abstraction for data. All data in a Python program is represented by objects or by relations between objects. (In a sense, and in conformance to Von Neumann’s model of a “stored program computer,” code is also represented by objects.)

Every object has an identity, a type and a value. An object’s *identity* never changes once it has been created; you may think of it as the object’s address in memory. The `is` operator compares the identity of two objects; the `id()` function returns an integer representing its identity (currently implemented as its address). An object’s *type* is also unchangeable.<sup>1</sup> An object’s type determines the operations that the object supports (e.g., “does it have a length?”) and also defines the possible values for objects of that type. The `type()` function returns an object’s type (which is an object itself). The *value* of some objects can change. Objects whose value can change are said to be *mutable*; objects whose value is unchangeable once they are created are called *immutable*. (The value of an immutable container object that contains a reference to a mutable object can change when the latter’s value is changed; however the container is still considered immutable, because the collection of objects it contains cannot be changed. So, immutability is not strictly the same as having an unchangeable value, it is more subtle.) An object’s mutability is determined by its type; for instance, numbers, strings and tuples are immutable, while dictionaries and lists are mutable.

Objects are never explicitly destroyed; however, when they become unreachable they may be garbage-collected. An implementation is allowed to postpone garbage collection or omit it altogether — it is a matter of implementation quality how garbage collection is implemented, as long as no objects are collected that are still reachable.

**CPython implementation detail:** CPython currently uses a reference-counting scheme with (optional) delayed detection of cyclically linked garbage, which collects most objects as soon as they become unreachable, but is not guaranteed to collect garbage containing circular references. See the documentation of the `gc` module for information on controlling the collection of cyclic garbage. Other implementations act differently and CPython may change. Do not depend on immediate finalization of objects when they become unreachable (ex: always close files).

Note that the use of the implementation’s tracing or debugging facilities may keep objects alive that would normally be collectable. Also note that catching an exception with a `try...except` statement may keep objects alive.

Some objects contain references to “external” resources such as open files or windows. It is understood that these resources are freed when the object is garbage-collected, but since garbage collection is not guaranteed to happen, such objects also provide an explicit way to release the external resource, usually a `close()` method. Programs are strongly recommended to explicitly close such objects. The `try...finally` statement provides a convenient way to do this.

Some objects contain references to other objects; these are called *containers*. Examples of containers are tuples, lists and dictionaries. The references are part of a container’s value. In most cases, when we talk about the value of a container, we imply the values, not the identities of the contained objects; however, when we talk about the mutability

---

<sup>1</sup> It is possible in some cases to change an object’s type, under certain controlled conditions. It generally isn’t a good idea though, since it can lead to some very strange behaviour if it is handled incorrectly.

of a container, only the identities of the immediately contained objects are implied. So, if an immutable container (like a tuple) contains a reference to a mutable object, its value changes if that mutable object is changed.

Types affect almost all aspects of object behavior. Even the importance of object identity is affected in some sense: for immutable types, operations that compute new values may actually return a reference to any existing object with the same type and value, while for mutable objects this is not allowed. E.g., after `a = 1; b = 1`, `a` and `b` may or may not refer to the same object with the value one, depending on the implementation, but after `c = []; d = []`, `c` and `d` are guaranteed to refer to two different, unique, newly created empty lists. (Note that `c = d = []` assigns the same object to both `c` and `d`.)

## 3.2 The standard type hierarchy

Below is a list of the types that are built into Python. Extension modules (written in C, Java, or other languages, depending on the implementation) can define additional types. Future versions of Python may add types to the type hierarchy (e.g., rational numbers, efficiently stored arrays of integers, etc.).

Some of the type descriptions below contain a paragraph listing ‘special attributes.’ These are attributes that provide access to the implementation and are not intended for general use. Their definition may change in the future.

**None** This type has a single value. There is a single object with this value. This object is accessed through the built-in name `None`. It is used to signify the absence of a value in many situations, e.g., it is returned from functions that don’t explicitly return anything. Its truth value is false.

**NotImplemented** This type has a single value. There is a single object with this value. This object is accessed through the built-in name `NotImplemented`. Numeric methods and rich comparison methods may return this value if they do not implement the operation for the operands provided. (The interpreter will then try the reflected operation, or some other fallback, depending on the operator.) Its truth value is true.

**Ellipsis** This type has a single value. There is a single object with this value. This object is accessed through the built-in name `Ellipsis`. It is used to indicate the presence of the `...` syntax in a slice. Its truth value is true.

**numbers.Number** These are created by numeric literals and returned as results by arithmetic operators and arithmetic built-in functions. Numeric objects are immutable; once created their value never changes. Python numbers are of course strongly related to mathematical numbers, but subject to the limitations of numerical representation in computers.

Python distinguishes between integers, floating point numbers, and complex numbers:

**numbers.Integral** These represent elements from the mathematical set of integers (positive and negative).

There are three types of integers:

**Plain integers** These represent numbers in the range -2147483648 through 2147483647. (The range may be larger on machines with a larger natural word size, but not smaller.) When the result of an operation would fall outside this range, the result is normally returned as a long integer (in some cases, the exception `OverflowError` is raised instead). For the purpose of shift and mask operations, integers are assumed to have a binary, 2’s complement notation using 32 or more bits, and hiding no bits from the user (i.e., all 4294967296 different bit patterns correspond to different values).

**Long integers** These represent numbers in an unlimited range, subject to available (virtual) memory only. For the purpose of shift and mask operations, a binary representation is assumed, and negative numbers are represented in a variant of 2’s complement which gives the illusion of an infinite string of sign bits extending to the left.

**Booleans** These represent the truth values `False` and `True`. The two objects representing the values `False` and `True` are the only Boolean objects. The Boolean type is a subtype of plain integers, and Boolean values behave like the values 0 and 1, respectively, in almost all contexts, the exception being that when converted to a string, the strings `"False"` or `"True"` are returned, respectively.

The rules for integer representation are intended to give the most meaningful interpretation of shift and mask operations involving negative integers and the least surprises when switching between the plain and long integer domains. Any operation, if it yields a result in the plain integer domain, will yield the same result in the long integer domain or when using mixed operands. The switch between domains is transparent to the programmer.

**numbers.Real (float)** These represent machine-level double precision floating point numbers. You are at the mercy of the underlying machine architecture (and C or Java implementation) for the accepted range and handling of overflow. Python does not support single-precision floating point numbers; the savings in processor and memory usage that are usually the reason for using these is dwarfed by the overhead of using objects in Python, so there is no reason to complicate the language with two kinds of floating point numbers.

**numbers.Complex** These represent complex numbers as a pair of machine-level double precision floating point numbers. The same caveats apply as for floating point numbers. The real and imaginary parts of a complex number  $z$  can be retrieved through the read-only attributes `z.real` and `z.imag`.

**Sequences** These represent finite ordered sets indexed by non-negative numbers. The built-in function `len()` returns the number of items of a sequence. When the length of a sequence is  $n$ , the index set contains the numbers 0, 1, ...,  $n-1$ . Item  $i$  of sequence  $a$  is selected by `a[i]`.

Sequences also support slicing: `a[i:j]` selects all items with index  $k$  such that  $i \leq k < j$ . When used as an expression, a slice is a sequence of the same type. This implies that the index set is renumbered so that it starts at 0.

Some sequences also support “extended slicing” with a third “step” parameter: `a[i:j:k]` selects all items of  $a$  with index  $x$  where  $x = i + n*k$ ,  $n \geq 0$  and  $i \leq x < j$ .

Sequences are distinguished according to their mutability:

**Immutable sequences** An object of an immutable sequence type cannot change once it is created. (If the object contains references to other objects, these other objects may be mutable and may be changed; however, the collection of objects directly referenced by an immutable object cannot change.)

The following types are immutable sequences:

**Strings** The items of a string are characters. There is no separate character type; a character is represented by a string of one item. Characters represent (at least) 8-bit bytes. The built-in functions `chr()` and `ord()` convert between characters and nonnegative integers representing the byte values. Bytes with the values 0-127 usually represent the corresponding ASCII values, but the interpretation of values is up to the program. The string data type is also used to represent arrays of bytes, e.g., to hold data read from a file.

(On systems whose native character set is not ASCII, strings may use EBCDIC in their internal representation, provided the functions `chr()` and `ord()` implement a mapping between ASCII and EBCDIC, and string comparison preserves the ASCII order. Or perhaps someone can propose a better rule?)

**Unicode** The items of a Unicode object are Unicode code units. A Unicode code unit is represented by a Unicode object of one item and can hold either a 16-bit or 32-bit value representing a Unicode ordinal (the maximum value for the ordinal is given in `sys.maxunicode`, and depends on how Python is configured at compile time). Surrogate pairs may be present in the Unicode object, and will be reported as two separate items. The built-in functions `unichr()` and `ord()` convert between code units and nonnegative integers representing the Unicode ordinals as defined in the Unicode Standard 3.0. Conversion from and to other encodings are possible through the Unicode method `encode()` and the built-in function `unicode()`.

**Tuples** The items of a tuple are arbitrary Python objects. Tuples of two or more items are formed by comma-separated lists of expressions. A tuple of one item (a ‘singleton’) can be formed by affixing

a comma to an expression (an expression by itself does not create a tuple, since parentheses must be usable for grouping of expressions). An empty tuple can be formed by an empty pair of parentheses.

**Mutable sequences** Mutable sequences can be changed after they are created. The subscription and slicing notations can be used as the target of assignment and `del` (delete) statements.

There are currently two intrinsic mutable sequence types:

**Lists** The items of a list are arbitrary Python objects. Lists are formed by placing a comma-separated list of expressions in square brackets. (Note that there are no special cases needed to form lists of length 0 or 1.)

**Byte Arrays** A bytearray object is a mutable array. They are created by the built-in `bytearray()` constructor. Aside from being mutable (and hence unhashable), byte arrays otherwise provide the same interface and functionality as immutable bytes objects.

The extension module `array` provides an additional example of a mutable sequence type.

**Set types** These represent unordered, finite sets of unique, immutable objects. As such, they cannot be indexed by any subscript. However, they can be iterated over, and the built-in function `len()` returns the number of items in a set. Common uses for sets are fast membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference.

For set elements, the same immutability rules apply as for dictionary keys. Note that numeric types obey the normal rules for numeric comparison: if two numbers compare equal (e.g., 1 and 1.0), only one of them can be contained in a set.

There are currently two intrinsic set types:

**Sets** These represent a mutable set. They are created by the built-in `set()` constructor and can be modified afterwards by several methods, such as `add()`.

**Frozen sets** These represent an immutable set. They are created by the built-in `frozenset()` constructor. As a frozenset is immutable and *hashable*, it can be used again as an element of another set, or as a dictionary key.

**Mappings** These represent finite sets of objects indexed by arbitrary index sets. The subscript notation `a[k]` selects the item indexed by `k` from the mapping `a`; this can be used in expressions and as the target of assignments or `del` statements. The built-in function `len()` returns the number of items in a mapping.

There is currently a single intrinsic mapping type:

**Dictionaries** These represent finite sets of objects indexed by nearly arbitrary values. The only types of values not acceptable as keys are values containing lists or dictionaries or other mutable types that are compared by value rather than by object identity, the reason being that the efficient implementation of dictionaries requires a key's hash value to remain constant. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (e.g., 1 and 1.0) then they can be used interchangeably to index the same dictionary entry.

Dictionaries are mutable; they can be created by the `{ . . . }` notation (see section *Dictionary displays*).

The extension modules `dbm`, `gdbm`, and `bsddb` provide additional examples of mapping types.

**Callable types** These are the types to which the function call operation (see section *Calls*) can be applied:

**User-defined functions** A user-defined function object is created by a function definition (see section *Function definitions*). It should be called with an argument list containing the same number of items as the function's formal parameter list.

Special attributes:

Attribute	Meaning	
<code>func_doc</code>	The function's documentation string, or <code>None</code> if unavailable	Writable
<code>__doc__</code>	Another way of spelling <code>func_doc</code>	Writable
<code>func_name</code>	The function's name	Writable
<code>__name__</code>	Another way of spelling <code>func_name</code>	Writable
<code>__module__</code>	The name of the module the function was defined in, or <code>None</code> if unavailable.	Writable
<code>func_defaults</code>	A tuple containing default argument values for those arguments that have defaults, or <code>None</code> if no arguments have a default value	Writable
<code>func_code</code>	The code object representing the compiled function body.	Writable
<code>func_globals</code>	A reference to the dictionary that holds the function's global variables — the global namespace of the module in which the function was defined.	Read-only
<code>func_dict</code>	The namespace supporting arbitrary function attributes.	Writable
<code>func_closure</code>	<code>None</code> or a tuple of cells that contain bindings for the function's free variables.	Read-only

Most of the attributes labelled “Writable” check the type of the assigned value. Changed in version 2.4: `func_name` is now writable. Function objects also support getting and setting arbitrary attributes, which can be used, for example, to attach metadata to functions. Regular attribute dot-notation is used to get and set such attributes. *Note that the current implementation only supports function attributes on user-defined functions. Function attributes on built-in functions may be supported in the future.*

Additional information about a function's definition can be retrieved from its code object; see the description of internal types below.

**User-defined methods** A user-defined method object combines a class, a class instance (or `None`) and any callable object (normally a user-defined function).

Special read-only attributes: `im_self` is the class instance object, `im_func` is the function object; `im_class` is the class of `im_self` for bound methods or the class that asked for the method for unbound methods; `__doc__` is the method's documentation (same as `im_func.__doc__`); `__name__` is the method name (same as `im_func.__name__`); `__module__` is the name of the module the method was defined in, or `None` if unavailable. Changed in version 2.2: `im_self` used to refer to the class that defined the method. Changed in version 2.6: For Python 3 forward-compatibility, `im_func` is also available as `__func__`, and `im_self` as `__self__`. Methods also support accessing (but not setting) the arbitrary function attributes on the underlying function object.

User-defined method objects may be created when getting an attribute of a class (perhaps via an instance of that class), if that attribute is a user-defined function object, an unbound user-defined method object, or a class method object. When the attribute is a user-defined method object, a new method object is only created if the class from which it is being retrieved is the same as, or a derived class of, the class stored in the original method object; otherwise, the original method object is used as it is.

When a user-defined method object is created by retrieving a user-defined function object from a class, its `im_self` attribute is `None` and the method object is said to be unbound. When one is created by retrieving a user-defined function object from a class via one of its instances, its `im_self` attribute is the instance, and the method object is said to be bound. In either case, the new method's `im_class` attribute is the class from which the retrieval takes place, and its `im_func` attribute is the original function object.

When a user-defined method object is created by retrieving another method object from a class or instance, the behaviour is the same as for a function object, except that the `im_func` attribute of the new instance is not the original method object but its `im_func` attribute.

When a user-defined method object is created by retrieving a class method object from a class or instance, its `im_self` attribute is the class itself (the same as the `im_class` attribute), and its `im_func` attribute is the function object underlying the class method.

When an unbound user-defined method object is called, the underlying function (`im_func`) is called, with the restriction that the first argument must be an instance of the proper class (`im_class`) or of a derived

class thereof.

When a bound user-defined method object is called, the underlying function (`im_func`) is called, inserting the class instance (`im_self`) in front of the argument list. For instance, when `C` is a class which contains a definition for a function `f()`, and `x` is an instance of `C`, calling `x.f(1)` is equivalent to calling `C.f(x, 1)`.

When a user-defined method object is derived from a class method object, the “class instance” stored in `im_self` will actually be the class itself, so that calling either `x.f(1)` or `C.f(1)` is equivalent to calling `f(C, 1)` where `f` is the underlying function.

Note that the transformation from function object to (unbound or bound) method object happens each time the attribute is retrieved from the class or instance. In some cases, a fruitful optimization is to assign the attribute to a local variable and call that local variable. Also notice that this transformation only happens for user-defined functions; other callable objects (and all non-callable objects) are retrieved without transformation. It is also important to note that user-defined functions which are attributes of a class instance are not converted to bound methods; this *only* happens when the function is an attribute of the class.

**Generator functions** A function or method which uses the `yield` statement (see section *The yield statement*) is called a *generator function*. Such a function, when called, always returns an iterator object which can be used to execute the body of the function: calling the iterator’s `next()` method will cause the function to execute until it provides a value using the `yield` statement. When the function executes a `return` statement or falls off the end, a `StopIteration` exception is raised and the iterator will have reached the end of the set of values to be returned.

**Built-in functions** A built-in function object is a wrapper around a C function. Examples of built-in functions are `len()` and `math.sin()` (`math` is a standard built-in module). The number and type of the arguments are determined by the C function. Special read-only attributes: `__doc__` is the function’s documentation string, or `None` if unavailable; `__name__` is the function’s name; `__self__` is set to `None` (but see the next item); `__module__` is the name of the module the function was defined in or `None` if unavailable.

**Built-in methods** This is really a different disguise of a built-in function, this time containing an object passed to the C function as an implicit extra argument. An example of a built-in method is `alist.append()`, assuming `alist` is a list object. In this case, the special read-only attribute `__self__` is set to the object denoted by `alist`.

**Class Types** Class types, or “new-style classes,” are callable. These objects normally act as factories for new instances of themselves, but variations are possible for class types that override `__new__()`. The arguments of the call are passed to `__new__()` and, in the typical case, to `__init__()` to initialize the new instance.

**Classic Classes** Class objects are described below. When a class object is called, a new class instance (also described below) is created and returned. This implies a call to the class’s `__init__()` method if it has one. Any arguments are passed on to the `__init__()` method. If there is no `__init__()` method, the class must be called without arguments.

**Class instances** Class instances are described below. Class instances are callable only when the class has a `__call__()` method; `x(arguments)` is a shorthand for `x.__call__(arguments)`.

**Modules** Modules are imported by the `import` statement (see section *The import statement*). A module object has a namespace implemented by a dictionary object (this is the dictionary referenced by the `func_globals` attribute of functions defined in the module). Attribute references are translated to lookups in this dictionary, e.g., `m.x` is equivalent to `m.__dict__["x"]`. A module object does not contain the code object used to initialize the module (since it isn’t needed once the initialization is done).

Attribute assignment updates the module’s namespace dictionary, e.g., `m.x = 1` is equivalent to `m.__dict__["x"] = 1`.

Special read-only attribute: `__dict__` is the module’s namespace as a dictionary object.

**CPython implementation detail:** Because of the way CPython clears module dictionaries, the module dictionary will be cleared when the module falls out of scope even if the dictionary still has live references. To avoid this, copy the dictionary or keep the module around while using its dictionary directly.

Predefined (writable) attributes: `__name__` is the module's name; `__doc__` is the module's documentation string, or `None` if unavailable; `__file__` is the pathname of the file from which the module was loaded, if it was loaded from a file. The `__file__` attribute is not present for C modules that are statically linked into the interpreter; for extension modules loaded dynamically from a shared library, it is the pathname of the shared library file.

**Classes** Both class types (new-style classes) and class objects (old-style/classic classes) are typically created by class definitions (see section *Class definitions*). A class has a namespace implemented by a dictionary object. Class attribute references are translated to lookups in this dictionary, e.g., `C.x` is translated to `C.__dict__["x"]` (although for new-style classes in particular there are a number of hooks which allow for other means of locating attributes). When the attribute name is not found there, the attribute search continues in the base classes. For old-style classes, the search is depth-first, left-to-right in the order of occurrence in the base class list. New-style classes use the more complex C3 method resolution order which behaves correctly even in the presence of 'diamond' inheritance structures where there are multiple inheritance paths leading back to a common ancestor. Additional details on the C3 MRO used by new-style classes can be found in the documentation accompanying the 2.3 release at <http://www.python.org/download/releases/2.3/mro/>.

When a class attribute reference (for class `C`, say) would yield a user-defined function object or an unbound user-defined method object whose associated class is either `C` or one of its base classes, it is transformed into an unbound user-defined method object whose `im_class` attribute is `C`. When it would yield a class method object, it is transformed into a bound user-defined method object whose `im_class` and `im_self` attributes are both `C`. When it would yield a static method object, it is transformed into the object wrapped by the static method object. See section *Implementing Descriptors* for another way in which attributes retrieved from a class may differ from those actually contained in its `__dict__` (note that only new-style classes support descriptors).

Class attribute assignments update the class's dictionary, never the dictionary of a base class.

A class object can be called (see above) to yield a class instance (see below).

Special attributes: `__name__` is the class name; `__module__` is the module name in which the class was defined; `__dict__` is the dictionary containing the class's namespace; `__bases__` is a tuple (possibly empty or a singleton) containing the base classes, in the order of their occurrence in the base class list; `__doc__` is the class's documentation string, or `None` if undefined.

**Class instances** A class instance is created by calling a class object (see above). A class instance has a namespace implemented as a dictionary which is the first place in which attribute references are searched. When an attribute is not found there, and the instance's class has an attribute by that name, the search continues with the class attributes. If a class attribute is found that is a user-defined function object or an unbound user-defined method object whose associated class is the class (call it `C`) of the instance for which the attribute reference was initiated or one of its bases, it is transformed into a bound user-defined method object whose `im_class` attribute is `C` and whose `im_self` attribute is the instance. Static method and class method objects are also transformed, as if they had been retrieved from class `C`; see above under "Classes". See section *Implementing Descriptors* for another way in which attributes of a class retrieved via its instances may differ from the objects actually stored in the class's `__dict__`. If no class attribute is found, and the object's class has a `__getattr__()` method, that is called to satisfy the lookup.

Attribute assignments and deletions update the instance's dictionary, never a class's dictionary. If the class has a `__setattr__()` or `__delattr__()` method, this is called instead of updating the instance dictionary directly.

Class instances can pretend to be numbers, sequences, or mappings if they have methods with certain special names. See section *Special method names*.

Special attributes: `__dict__` is the attribute dictionary; `__class__` is the instance's class.

**Files** A file object represents an open file. File objects are created by the `open()` built-in function, and also by `os.popen()`, `os.fdopen()`, and the `makefile()` method of socket objects (and perhaps by other functions or methods provided by extension modules). The objects `sys.stdin`, `sys.stdout` and `sys.stderr` are initialized to file objects corresponding to the interpreter's standard input, output and error streams. See *builtin-file-objects* for complete documentation of file objects.

**Internal types** A few types used internally by the interpreter are exposed to the user. Their definitions may change with future versions of the interpreter, but they are mentioned here for completeness.

**Code objects** Code objects represent *byte-compiled* executable Python code, or *bytecode*. The difference between a code object and a function object is that the function object contains an explicit reference to the function's globals (the module in which it was defined), while a code object contains no context; also the default argument values are stored in the function object, not in the code object (because they represent values calculated at run-time). Unlike function objects, code objects are immutable and contain no references (directly or indirectly) to mutable objects.

Special read-only attributes: `co_name` gives the function name; `co_argcount` is the number of positional arguments (including arguments with default values); `co_nlocals` is the number of local variables used by the function (including arguments); `co_varnames` is a tuple containing the names of the local variables (starting with the argument names); `co_cellvars` is a tuple containing the names of local variables that are referenced by nested functions; `co_freevars` is a tuple containing the names of free variables; `co_code` is a string representing the sequence of bytecode instructions; `co_consts` is a tuple containing the literals used by the bytecode; `co_names` is a tuple containing the names used by the bytecode; `co_filename` is the filename from which the code was compiled; `co_firstlineno` is the first line number of the function; `co_lnotab` is a string encoding the mapping from bytecode offsets to line numbers (for details see the source code of the interpreter); `co_stacksize` is the required stack size (including local variables); `co_flags` is an integer encoding a number of flags for the interpreter.

The following flag bits are defined for `co_flags`: bit `0x04` is set if the function uses the `*arguments` syntax to accept an arbitrary number of positional arguments; bit `0x08` is set if the function uses the `**keywords` syntax to accept arbitrary keyword arguments; bit `0x20` is set if the function is a generator.

Future feature declarations (`from __future__ import division`) also use bits in `co_flags` to indicate whether a code object was compiled with a particular feature enabled: bit `0x2000` is set if the function was compiled with future division enabled; bits `0x10` and `0x1000` were used in earlier versions of Python.

Other bits in `co_flags` are reserved for internal use.

If a code object represents a function, the first item in `co_consts` is the documentation string of the function, or `None` if undefined.

**Frame objects** Frame objects represent execution frames. They may occur in traceback objects (see below).

Special read-only attributes: `f_back` is to the previous stack frame (towards the caller), or `None` if this is the bottom stack frame; `f_code` is the code object being executed in this frame; `f_locals` is the dictionary used to look up local variables; `f_globals` is used for global variables; `f_builtins` is used for built-in (intrinsic) names; `f_restricted` is a flag indicating whether the function is executing in restricted execution mode; `f_lasti` gives the precise instruction (this is an index into the bytecode string of the code object).

Special writable attributes: `f_trace`, if not `None`, is a function called at the start of each source code line (this is used by the debugger); `f_exc_type`, `f_exc_value`, `f_exc_traceback` represent the last exception raised in the parent frame provided another exception was ever raised in the current frame (in all other cases they are `None`); `f_lineno` is the current line number of the frame — writing to this from within a trace function jumps to the given line (only for the bottom-most frame). A debugger can implement a Jump command (aka Set Next Statement) by writing to `f_lineno`.

**Traceback objects** Traceback objects represent a stack trace of an exception. A traceback object is created

when an exception occurs. When the search for an exception handler unwinds the execution stack, at each unwound level a traceback object is inserted in front of the current traceback. When an exception handler is entered, the stack trace is made available to the program. (See section *The try statement*.) It is accessible as `sys.exc_traceback`, and also as the third item of the tuple returned by `sys.exc_info()`. The latter is the preferred interface, since it works correctly when the program is using multiple threads. When the program contains no suitable handler, the stack trace is written (nicely formatted) to the standard error stream; if the interpreter is interactive, it is also made available to the user as `sys.last_traceback`.

Special read-only attributes: `tb_next` is the next level in the stack trace (towards the frame where the exception occurred), or `None` if there is no next level; `tb_frame` points to the execution frame of the current level; `tb_lineno` gives the line number where the exception occurred; `tb_lasti` indicates the precise instruction. The line number and last instruction in the traceback may differ from the line number of its frame object if the exception occurred in a `try` statement with no matching `except` clause or with a `finally` clause.

**Slice objects** Slice objects are used to represent slices when *extended slice syntax* is used. This is a slice using two colons, or multiple slices or ellipses separated by commas, e.g., `a[i:j:step]`, `a[i:j, k:l]`, or `a[... , i:j]`. They are also created by the built-in `slice()` function.

Special read-only attributes: `start` is the lower bound; `stop` is the upper bound; `step` is the step value; each is `None` if omitted. These attributes can have any type.

Slice objects support one method:

`slice.indices(self, length)`

This method takes a single integer argument *length* and computes information about the extended slice that the slice object would describe if applied to a sequence of *length* items. It returns a tuple of three integers; respectively these are the *start* and *stop* indices and the *step* or stride length of the slice. Missing or out-of-bounds indices are handled in a manner consistent with regular slices. New in version 2.3.

**Static method objects** Static method objects provide a way of defeating the transformation of function objects to method objects described above. A static method object is a wrapper around any other object, usually a user-defined method object. When a static method object is retrieved from a class or a class instance, the object actually returned is the wrapped object, which is not subject to any further transformation. Static method objects are not themselves callable, although the objects they wrap usually are. Static method objects are created by the built-in `staticmethod()` constructor.

**Class method objects** A class method object, like a static method object, is a wrapper around another object that alters the way in which that object is retrieved from classes and class instances. The behaviour of class method objects upon such retrieval is described above, under “User-defined methods”. Class method objects are created by the built-in `classmethod()` constructor.

### 3.3 New-style and classic classes

Classes and instances come in two flavors: old-style (or classic) and new-style.

Up to Python 2.1, old-style classes were the only flavour available to the user. The concept of (old-style) class is unrelated to the concept of type: if *x* is an instance of an old-style class, then `x.__class__` designates the class of *x*, but `type(x)` is always `<type 'instance'>`. This reflects the fact that all old-style instances, independently of their class, are implemented with a single built-in type, called `instance`.

New-style classes were introduced in Python 2.2 to unify classes and types. A new-style class is neither more nor less than a user-defined type. If *x* is an instance of a new-style class, then `type(x)` is typically the same as `x.__class__` (although this is not guaranteed - a new-style class instance is permitted to override the value returned for `x.__class__`).

The major motivation for introducing new-style classes is to provide a unified object model with a full meta-model. It also has a number of practical benefits, like the ability to subclass most built-in types, or the introduction of “descriptors”, which enable computed properties.

For compatibility reasons, classes are still old-style by default. New-style classes are created by specifying another new-style class (i.e. a type) as a parent class, or the “top-level type” `object` if no other parent is needed. The behaviour of new-style classes differs from that of old-style classes in a number of important details in addition to what `type()` returns. Some of these changes are fundamental to the new object model, like the way special methods are invoked. Others are “fixes” that could not be implemented before for compatibility concerns, like the method resolution order in case of multiple inheritance.

While this manual aims to provide comprehensive coverage of Python’s class mechanics, it may still be lacking in some areas when it comes to its coverage of new-style classes. Please see <http://www.python.org/doc/newstyle/> for sources of additional information.

Old-style classes are removed in Python 3, leaving only the semantics of new-style classes.

## 3.4 Special method names

A class can implement certain operations that are invoked by special syntax (such as arithmetic operations or subscripting and slicing) by defining methods with special names. This is Python’s approach to *operator overloading*, allowing classes to define their own behavior with respect to language operators. For instance, if a class defines a method named `__getitem__()`, and `x` is an instance of this class, then `x[i]` is roughly equivalent to `x.__getitem__(i)` for old-style classes and `type(x).__getitem__(x, i)` for new-style classes. Except where mentioned, attempts to execute an operation raise an exception when no appropriate method is defined (typically `AttributeError` or `TypeError`).

When implementing a class that emulates any built-in type, it is important that the emulation only be implemented to the degree that it makes sense for the object being modelled. For example, some sequences may work well with retrieval of individual elements, but extracting a slice may not make sense. (One example of this is the `NodeList` interface in the W3C’s Document Object Model.)

### 3.4.1 Basic customization

`object.__new__(cls[, ...])`

Called to create a new instance of class `cls`. `__new__()` is a static method (special-cased so you need not declare it as such) that takes the class of which an instance was requested as its first argument. The remaining arguments are those passed to the object constructor expression (the call to the class). The return value of `__new__()` should be the new object instance (usually an instance of `cls`).

Typical implementations create a new instance of the class by invoking the superclass’s `__new__()` method using `super(currentclass, cls).__new__(cls[, ...])` with appropriate arguments and then modifying the newly-created instance as necessary before returning it.

If `__new__()` returns an instance of `cls`, then the new instance’s `__init__()` method will be invoked like `__init__(self[, ...])`, where `self` is the new instance and the remaining arguments are the same as were passed to `__new__()`.

If `__new__()` does not return an instance of `cls`, then the new instance’s `__init__()` method will not be invoked.

`__new__()` is intended mainly to allow subclasses of immutable types (like `int`, `str`, or `tuple`) to customize instance creation. It is also commonly overridden in custom metaclasses in order to customize class creation.

`object.__init__(self[, ...])`

Called when the instance is created. The arguments are those passed to the class constructor expression. If a base class has an `__init__()` method, the derived class's `__init__()` method, if any, must explicitly call it to ensure proper initialization of the base class part of the instance; for example: `BaseClass.__init__(self, [args...])`. As a special constraint on constructors, no value may be returned; doing so will cause a `TypeError` to be raised at runtime.

`object.__del__(self)`

Called when the instance is about to be destroyed. This is also called a destructor. If a base class has a `__del__()` method, the derived class's `__del__()` method, if any, must explicitly call it to ensure proper deletion of the base class part of the instance. Note that it is possible (though not recommended!) for the `__del__()` method to postpone destruction of the instance by creating a new reference to it. It may then be called at a later time when this new reference is deleted. It is not guaranteed that `__del__()` methods are called for objects that still exist when the interpreter exits.

**Note:** `del x` doesn't directly call `x.__del__()` — the former decrements the reference count for `x` by one, and the latter is only called when `x`'s reference count reaches zero. Some common situations that may prevent the reference count of an object from going to zero include: circular references between objects (e.g., a doubly-linked list or a tree data structure with parent and child pointers); a reference to the object on the stack frame of a function that caught an exception (the traceback stored in `sys.exc_traceback` keeps the stack frame alive); or a reference to the object on the stack frame that raised an unhandled exception in interactive mode (the traceback stored in `sys.last_traceback` keeps the stack frame alive). The first situation can only be remedied by explicitly breaking the cycles; the latter two situations can be resolved by storing `None` in `sys.exc_traceback` or `sys.last_traceback`. Circular references which are garbage are detected when the option cycle detector is enabled (it's on by default), but can only be cleaned up if there are no Python-level `__del__()` methods involved. Refer to the documentation for the `gc` module for more information about how `__del__()` methods are handled by the cycle detector, particularly the description of the `garbage` value.

**Warning:** Due to the precarious circumstances under which `__del__()` methods are invoked, exceptions that occur during their execution are ignored, and a warning is printed to `sys.stderr` instead. Also, when `__del__()` is invoked in response to a module being deleted (e.g., when execution of the program is done), other globals referenced by the `__del__()` method may already have been deleted or in the process of being torn down (e.g. the import machinery shutting down). For this reason, `__del__()` methods should do the absolute minimum needed to maintain external invariants. Starting with version 1.5, Python guarantees that globals whose name begins with a single underscore are deleted from their module before other globals are deleted; if no other references to such globals exist, this may help in assuring that imported modules are still available at the time when the `__del__()` method is called.

See also the `-R` command-line option.

`object.__repr__(self)`

Called by the `repr()` built-in function and by string conversions (reverse quotes) to compute the “official” string representation of an object. If at all possible, this should look like a valid Python expression that could be used to recreate an object with the same value (given an appropriate environment). If this is not possible, a string of the form `<...some useful description...>` should be returned. The return value must be a string object. If a class defines `__repr__()` but not `__str__()`, then `__repr__()` is also used when an “informal” string representation of instances of that class is required.

This is typically used for debugging, so it is important that the representation is information-rich and unambiguous.

`object.__str__(self)`

Called by the `str()` built-in function and by the `print` statement to compute the “informal” string representation of an object. This differs from `__repr__()` in that it does not have to be a valid Python expression: a more convenient or concise representation may be used instead. The return value must be a string object.

```
object.__lt__(self, other)
object.__le__(self, other)
object.__eq__(self, other)
object.__ne__(self, other)
object.__gt__(self, other)
object.__ge__(self, other)
```

New in version 2.1. These are the so-called “rich comparison” methods, and are called for comparison operators in preference to `__cmp__()` below. The correspondence between operator symbols and method names is as follows: `x<y` calls `x.__lt__(y)`, `x<=y` calls `x.__le__(y)`, `x==y` calls `x.__eq__(y)`, `x!=y` and `x<>y` call `x.__ne__(y)`, `x>y` calls `x.__gt__(y)`, and `x>=y` calls `x.__ge__(y)`.

A rich comparison method may return the singleton `NotImplemented` if it does not implement the operation for a given pair of arguments. By convention, `False` and `True` are returned for a successful comparison. However, these methods can return any value, so if the comparison operator is used in a Boolean context (e.g., in the condition of an `if` statement), Python will call `bool()` on the value to determine if the result is true or false.

There are no implied relationships among the comparison operators. The truth of `x==y` does not imply that `x!=y` is false. Accordingly, when defining `__eq__()`, one should also define `__ne__()` so that the operators will behave as expected. See the paragraph on `__hash__()` for some important notes on creating *hashable* objects which support custom comparison operations and are usable as dictionary keys.

There are no swapped-argument versions of these methods (to be used when the left argument does not support the operation but the right argument does); rather, `__lt__()` and `__gt__()` are each other’s reflection, `__le__()` and `__ge__()` are each other’s reflection, and `__eq__()` and `__ne__()` are their own reflection.

Arguments to rich comparison methods are never coerced.

To automatically generate ordering operations from a single root operation, see `functools.total_ordering()`.

```
object.__cmp__(self, other)
```

Called by comparison operations if rich comparison (see above) is not defined. Should return a negative integer if `self < other`, zero if `self == other`, a positive integer if `self > other`. If no `__cmp__()`, `__eq__()` or `__ne__()` operation is defined, class instances are compared by object identity (“address”). See also the description of `__hash__()` for some important notes on creating *hashable* objects which support custom comparison operations and are usable as dictionary keys. (Note: the restriction that exceptions are not propagated by `__cmp__()` has been removed since Python 1.5.)

```
object.__rcmp__(self, other)
```

Changed in version 2.1: No longer supported.

```
object.__hash__(self)
```

Called by built-in function `hash()` and for operations on members of hashed collections including `set`, `frozenset`, and `dict`. `__hash__()` should return an integer. The only required property is that objects which compare equal have the same hash value; it is advised to somehow mix together (e.g. using exclusive or) the hash values for the components of the object that also play a part in comparison of objects.

If a class does not define a `__cmp__()` or `__eq__()` method it should not define a `__hash__()` operation either; if it defines `__cmp__()` or `__eq__()` but not `__hash__()`, its instances will not be usable in hashed collections. If a class defines mutable objects and implements a `__cmp__()` or `__eq__()` method, it should not implement `__hash__()`, since hashable collection implementations require that a object’s hash value is immutable (if the object’s hash value changes, it will be in the wrong hash bucket).

User-defined classes have `__cmp__()` and `__hash__()` methods by default; with them, all objects compare unequal (except with themselves) and `x.__hash__()` returns `id(x)`.

Classes which inherit a `__hash__()` method from a parent class but change the meaning of `__cmp__()` or

`__eq__()` such that the hash value returned is no longer appropriate (e.g. by switching to a value-based concept of equality instead of the default identity based equality) can explicitly flag themselves as being unhashable by setting `__hash__ = None` in the class definition. Doing so means that not only will instances of the class raise an appropriate `TypeError` when a program attempts to retrieve their hash value, but they will also be correctly identified as unhashable when checking `isinstance(obj, collections.Hashable)` (unlike classes which define their own `__hash__()` to explicitly raise `TypeError`). Changed in version 2.5: `__hash__()` may now also return a long integer object; the 32-bit integer is then derived from the hash of that object. Changed in version 2.6: `__hash__` may now be set to `None` to explicitly flag instances of a class as unhashable.

`object.__nonzero__(self)`

Called to implement truth value testing and the built-in operation `bool()`; should return `False` or `True`, or their integer equivalents 0 or 1. When this method is not defined, `__len__()` is called, if it is defined, and the object is considered true if its result is nonzero. If a class defines neither `__len__()` nor `__nonzero__()`, all its instances are considered true.

`object.__unicode__(self)`

Called to implement `unicode()` built-in; should return a Unicode object. When this method is not defined, string conversion is attempted, and the result of string conversion is converted to Unicode using the system default encoding.

### 3.4.2 Customizing attribute access

The following methods can be defined to customize the meaning of attribute access (use of, assignment to, or deletion of `x.name`) for class instances.

`object.__getattr__(self, name)`

Called when an attribute lookup has not found the attribute in the usual places (i.e. it is not an instance attribute nor is it found in the class tree for `self`). `name` is the attribute name. This method should return the (computed) attribute value or raise an `AttributeError` exception.

Note that if the attribute is found through the normal mechanism, `__getattr__()` is not called. (This is an intentional asymmetry between `__getattr__()` and `__setattr__()`.) This is done both for efficiency reasons and because otherwise `__getattr__()` would have no way to access other attributes of the instance. Note that at least for instance variables, you can fake total control by not inserting any values in the instance attribute dictionary (but instead inserting them in another object). See the `__getattribute__()` method below for a way to actually get total control in new-style classes.

`object.__setattr__(self, name, value)`

Called when an attribute assignment is attempted. This is called instead of the normal mechanism (i.e. store the value in the instance dictionary). `name` is the attribute name, `value` is the value to be assigned to it.

If `__setattr__()` wants to assign to an instance attribute, it should not simply execute `self.name = value` — this would cause a recursive call to itself. Instead, it should insert the value in the dictionary of instance attributes, e.g., `self.__dict__[name] = value`. For new-style classes, rather than accessing the instance dictionary, it should call the base class method with the same name, for example, `object.__setattr__(self, name, value)`.

`object.__delattr__(self, name)`

Like `__setattr__()` but for attribute deletion instead of assignment. This should only be implemented if `del obj.name` is meaningful for the object.

#### More attribute access for new-style classes

The following methods only apply to new-style classes.

`object.__getattr__`(*self*, *name*)

Called unconditionally to implement attribute accesses for instances of the class. If the class also defines `__getattr__()`, the latter will not be called unless `__getattr__()` either calls it explicitly or raises an `AttributeError`. This method should return the (computed) attribute value or raise an `AttributeError` exception. In order to avoid infinite recursion in this method, its implementation should always call the base class method with the same name to access any attributes it needs, for example, `object.__getattr__(self, name)`.

---

**Note:** This method may still be bypassed when looking up special methods as the result of implicit invocation via language syntax or built-in functions. See *Special method lookup for new-style classes*.

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### Implementing Descriptors

The following methods only apply when an instance of the class containing the method (a so-called *descriptor* class) appears in an *owner* class (the descriptor must be in either the owner's class dictionary or in the class dictionary for one of its parents). In the examples below, “the attribute” refers to the attribute whose name is the key of the property in the owner class' `__dict__`.

`object.__get__`(*self*, *instance*, *owner*)

Called to get the attribute of the owner class (class attribute access) or of an instance of that class (instance attribute access). *owner* is always the owner class, while *instance* is the instance that the attribute was accessed through, or `None` when the attribute is accessed through the *owner*. This method should return the (computed) attribute value or raise an `AttributeError` exception.

`object.__set__`(*self*, *instance*, *value*)

Called to set the attribute on an instance *instance* of the owner class to a new value, *value*.

`object.__delete__`(*self*, *instance*)

Called to delete the attribute on an instance *instance* of the owner class.

### Invoking Descriptors

In general, a descriptor is an object attribute with “binding behavior”, one whose attribute access has been overridden by methods in the descriptor protocol: `__get__()`, `__set__()`, and `__delete__()`. If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object's dictionary. For instance, `a.x` has a lookup chain starting with `a.__dict__['x']`, then `type(a).__dict__['x']`, and continuing through the base classes of `type(a)` excluding metaclasses.

However, if the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined and how they were called. Note that descriptors are only invoked for new style objects or classes (ones that subclass `object()` or `type()`).

The starting point for descriptor invocation is a binding, `a.x`. How the arguments are assembled depends on `a`:

**Direct Call** The simplest and least common call is when user code directly invokes a descriptor method:  
`x.__get__(a)`.

**Instance Binding** If binding to a new-style object instance, `a.x` is transformed into the call:  
`type(a).__dict__['x'].__get__(a, type(a))`.

**Class Binding** If binding to a new-style class, `A.x` is transformed into the call:  
`A.__dict__['x'].__get__(None, A)`.

**Super Binding** If `a` is an instance of `super`, then the binding `super(B, obj).m()` searches `obj.__class__.__mro__` for the base class `A` immediately preceding `B` and then invokes the descriptor with the call: `A.__dict__['m'].__get__(obj, obj.__class__)`.

For instance bindings, the precedence of descriptor invocation depends on the which descriptor methods are defined. A descriptor can define any combination of `__get__()`, `__set__()` and `__delete__()`. If it does not define `__get__()`, then accessing the attribute will return the descriptor object itself unless there is a value in the object's instance dictionary. If the descriptor defines `__set__()` and/or `__delete__()`, it is a data descriptor; if it defines neither, it is a non-data descriptor. Normally, data descriptors define both `__get__()` and `__set__()`, while non-data descriptors have just the `__get__()` method. Data descriptors with `__set__()` and `__get__()` defined always override a redefinition in an instance dictionary. In contrast, non-data descriptors can be overridden by instances.

Python methods (including `staticmethod()` and `classmethod()`) are implemented as non-data descriptors. Accordingly, instances can redefine and override methods. This allows individual instances to acquire behaviors that differ from other instances of the same class.

The `property()` function is implemented as a data descriptor. Accordingly, instances cannot override the behavior of a property.

## `__slots__`

By default, instances of both old and new-style classes have a dictionary for attribute storage. This wastes space for objects having very few instance variables. The space consumption can become acute when creating large numbers of instances.

The default can be overridden by defining `__slots__` in a new-style class definition. The `__slots__` declaration takes a sequence of instance variables and reserves just enough space in each instance to hold a value for each variable. Space is saved because `__dict__` is not created for each instance.

## `__slots__`

This class variable can be assigned a string, iterable, or sequence of strings with variable names used by instances. If defined in a new-style class, `__slots__` reserves space for the declared variables and prevents the automatic creation of `__dict__` and `__weakref__` for each instance. New in version 2.2.

Notes on using `__slots__`

- When inheriting from a class without `__slots__`, the `__dict__` attribute of that class will always be accessible, so a `__slots__` definition in the subclass is meaningless.
- Without a `__dict__` variable, instances cannot be assigned new variables not listed in the `__slots__` definition. Attempts to assign to an unlisted variable name raises `AttributeError`. If dynamic assignment of new variables is desired, then add `'__dict__'` to the sequence of strings in the `__slots__` declaration. Changed in version 2.3: Previously, adding `'__dict__'` to the `__slots__` declaration would not enable the assignment of new attributes not specifically listed in the sequence of instance variable names.
- Without a `__weakref__` variable for each instance, classes defining `__slots__` do not support weak references to its instances. If weak reference support is needed, then add `'__weakref__'` to the sequence of strings in the `__slots__` declaration. Changed in version 2.3: Previously, adding `'__weakref__'` to the `__slots__` declaration would not enable support for weak references.
- `__slots__` are implemented at the class level by creating descriptors (*Implementing Descriptors*) for each variable name. As a result, class attributes cannot be used to set default values for instance variables defined by `__slots__`; otherwise, the class attribute would overwrite the descriptor assignment.
- The action of a `__slots__` declaration is limited to the class where it is defined. As a result, subclasses will have a `__dict__` unless they also define `__slots__` (which must only contain names of any *additional* slots).

- If a class defines a slot also defined in a base class, the instance variable defined by the base class slot is inaccessible (except by retrieving its descriptor directly from the base class). This renders the meaning of the program undefined. In the future, a check may be added to prevent this.
- Nonempty `__slots__` does not work for classes derived from “variable-length” built-in types such as `long`, `str` and `tuple`.
- Any non-string iterable may be assigned to `__slots__`. Mappings may also be used; however, in the future, special meaning may be assigned to the values corresponding to each key.
- `__class__` assignment works only if both classes have the same `__slots__`. Changed in version 2.6: Previously, `__class__` assignment raised an error if either new or old class had `__slots__`.

### 3.4.3 Customizing class creation

By default, new-style classes are constructed using `type()`. A class definition is read into a separate namespace and the value of class name is bound to the result of `type(name, bases, dict)`.

When the class definition is read, if `__metaclass__` is defined then the callable assigned to it will be called instead of `type()`. This allows classes or functions to be written which monitor or alter the class creation process:

- Modifying the class dictionary prior to the class being created.
- Returning an instance of another class – essentially performing the role of a factory function.

These steps will have to be performed in the metaclass’s `__new__()` method – `type.__new__()` can then be called from this method to create a class with different properties. This example adds a new element to the class dictionary before creating the class:

```
class metacls(type):
    def __new__(mcs, name, bases, dict):
        dict['foo'] = 'metacls was here'
        return type.__new__(mcs, name, bases, dict)
```

You can of course also override other class methods (or add new methods); for example defining a custom `__call__()` method in the metaclass allows custom behavior when the class is called, e.g. not always creating a new instance.

#### `__metaclass__`

This variable can be any callable accepting arguments for `name`, `bases`, and `dict`. Upon class creation, the callable is used instead of the built-in `type()`. New in version 2.2.

The appropriate metaclass is determined by the following precedence rules:

- If `dict['__metaclass__']` exists, it is used.
- Otherwise, if there is at least one base class, its metaclass is used (this looks for a `__class__` attribute first and if not found, uses its type).
- Otherwise, if a global variable named `__metaclass__` exists, it is used.
- Otherwise, the old-style, classic metaclass (`types.ClassType`) is used.

The potential uses for metaclasses are boundless. Some ideas that have been explored including logging, interface checking, automatic delegation, automatic property creation, proxies, frameworks, and automatic resource locking/synchronization.

### 3.4.4 Customizing instance and subclass checks

New in version 2.6. The following methods are used to override the default behavior of the `isinstance()` and `issubclass()` built-in functions.

In particular, the metaclass `abc.ABCMeta` implements these methods in order to allow the addition of Abstract Base Classes (ABCs) as “virtual base classes” to any class or type (including built-in types), including other ABCs.

```
class.__instancecheck__(self, instance)
    Return true if instance should be considered a (direct or indirect) instance of class. If defined, called to implement isinstance(instance, class).
```

```
class.__subclasscheck__(self, subclass)
    Return true if subclass should be considered a (direct or indirect) subclass of class. If defined, called to implement issubclass(subclass, class).
```

Note that these methods are looked up on the type (metaclass) of a class. They cannot be defined as class methods in the actual class. This is consistent with the lookup of special methods that are called on instances, only in this case the instance is itself a class.

#### See Also:

**PEP 3119 - Introducing Abstract Base Classes** Includes the specification for customizing `isinstance()` and `issubclass()` behavior through `__instancecheck__()` and `__subclasscheck__()`, with motivation for this functionality in the context of adding Abstract Base Classes (see the `abc` module) to the language.

### 3.4.5 Emulating callable objects

```
object.__call__(self[, args...])
    Called when the instance is “called” as a function; if this method is defined, x(arg1, arg2, ...) is a shorthand for x.__call__(arg1, arg2, ...).
```

### 3.4.6 Emulating container types

The following methods can be defined to implement container objects. Containers usually are sequences (such as lists or tuples) or mappings (like dictionaries), but can represent other containers as well. The first set of methods is used either to emulate a sequence or to emulate a mapping; the difference is that for a sequence, the allowable keys should be the integers  $k$  for which  $0 \leq k < N$  where  $N$  is the length of the sequence, or slice objects, which define a range of items. (For backwards compatibility, the method `__getslice__()` (see below) can also be defined to handle simple, but not extended slices.) It is also recommended that mappings provide the methods `keys()`, `values()`, `items()`, `has_key()`, `get()`, `clear()`, `setdefault()`, `iterkeys()`, `itervalues()`, `iteritems()`, `pop()`, `popitem()`, `copy()`, and `update()` behaving similar to those for Python’s standard dictionary objects. The `UserDict` module provides a `DictMixin` class to help create those methods from a base set of `__getitem__()`, `__setitem__()`, `__delitem__()`, and `keys()`. Mutable sequences should provide methods `append()`, `count()`, `index()`, `extend()`, `insert()`, `pop()`, `remove()`, `reverse()` and `sort()`, like Python standard list objects. Finally, sequence types should implement addition (meaning concatenation) and multiplication (meaning repetition) by defining the methods `__add__()`, `__radd__()`, `__iadd__()`, `__mul__()`, `__rmul__()` and `__imul__()` described below; they should not define `__coerce__()` or other numerical operators. It is recommended that both mappings and sequences implement the `__contains__()` method to allow efficient use of the `in` operator; for mappings, `in` should be equivalent of `has_key()`; for sequences, it should search through the values. It is further recommended that both mappings and sequences implement the `__iter__()` method to allow efficient iteration through the container; for mappings, `__iter__()` should be the same as `iterkeys()`; for sequences, it should iterate through the values.

object.**\_\_len\_\_**(*self*)

Called to implement the built-in function `len()`. Should return the length of the object, an integer  $\geq 0$ . Also, an object that doesn't define a `__nonzero__()` method and whose `__len__()` method returns zero is considered to be false in a Boolean context.

object.**\_\_getitem\_\_**(*self*, *key*)

Called to implement evaluation of `self[key]`. For sequence types, the accepted keys should be integers and slice objects. Note that the special interpretation of negative indexes (if the class wishes to emulate a sequence type) is up to the `__getitem__()` method. If *key* is of an inappropriate type, `TypeError` may be raised; if of a value outside the set of indexes for the sequence (after any special interpretation of negative values), `IndexError` should be raised. For mapping types, if *key* is missing (not in the container), `KeyError` should be raised.

---

**Note:** `for` loops expect that an `IndexError` will be raised for illegal indexes to allow proper detection of the end of the sequence.

---

object.**\_\_setitem\_\_**(*self*, *key*, *value*)

Called to implement assignment to `self[key]`. Same note as for `__getitem__()`. This should only be implemented for mappings if the objects support changes to the values for keys, or if new keys can be added, or for sequences if elements can be replaced. The same exceptions should be raised for improper *key* values as for the `__getitem__()` method.

object.**\_\_delitem\_\_**(*self*, *key*)

Called to implement deletion of `self[key]`. Same note as for `__getitem__()`. This should only be implemented for mappings if the objects support removal of keys, or for sequences if elements can be removed from the sequence. The same exceptions should be raised for improper *key* values as for the `__getitem__()` method.

object.**\_\_iter\_\_**(*self*)

This method is called when an iterator is required for a container. This method should return a new iterator object that can iterate over all the objects in the container. For mappings, it should iterate over the keys of the container, and should also be made available as the method `iterkeys()`.

Iterator objects also need to implement this method; they are required to return themselves. For more information on iterator objects, see *typeiter*.

object.**\_\_reversed\_\_**(*self*)

Called (if present) by the `reversed()` built-in to implement reverse iteration. It should return a new iterator object that iterates over all the objects in the container in reverse order.

If the `__reversed__()` method is not provided, the `reversed()` built-in will fall back to using the sequence protocol (`__len__()` and `__getitem__()`). Objects that support the sequence protocol should only provide `__reversed__()` if they can provide an implementation that is more efficient than the one provided by `reversed()`. New in version 2.6.

The membership test operators (`in` and `not in`) are normally implemented as an iteration through a sequence. However, container objects can supply the following special method with a more efficient implementation, which also does not require the object be a sequence.

object.**\_\_contains\_\_**(*self*, *item*)

Called to implement membership test operators. Should return true if *item* is in *self*, false otherwise. For mapping objects, this should consider the keys of the mapping rather than the values or the key-item pairs.

For objects that don't define `__contains__()`, the membership test first tries iteration via `__iter__()`, then the old sequence iteration protocol via `__getitem__()`, see *this section in the language reference*.

### 3.4.7 Additional methods for emulation of sequence types

The following optional methods can be defined to further emulate sequence objects. Immutable sequences methods should at most only define `__getslice__()`; mutable sequences might define all three methods.

`object.__getslice__(self, i, j)`

Deprecated since version 2.0: Support slice objects as parameters to the `__getitem__()` method. (However, built-in types in CPython currently still implement `__getslice__()`. Therefore, you have to override it in derived classes when implementing slicing.) Called to implement evaluation of `self[i:j]`. The returned object should be of the same type as `self`. Note that missing `i` or `j` in the slice expression are replaced by zero or `sys.maxint`, respectively. If negative indexes are used in the slice, the length of the sequence is added to that index. If the instance does not implement the `__len__()` method, an `AttributeError` is raised. No guarantee is made that indexes adjusted this way are not still negative. Indexes which are greater than the length of the sequence are not modified. If no `__getslice__()` is found, a slice object is created instead, and passed to `__getitem__()` instead.

`object.__setslice__(self, i, j, sequence)`

Called to implement assignment to `self[i:j]`. Same notes for `i` and `j` as for `__getslice__()`.

This method is deprecated. If no `__setslice__()` is found, or for extended slicing of the form `self[i:j:k]`, a slice object is created, and passed to `__setitem__()`, instead of `__setslice__()` being called.

`object.__delslice__(self, i, j)`

Called to implement deletion of `self[i:j]`. Same notes for `i` and `j` as for `__getslice__()`. This method is deprecated. If no `__delslice__()` is found, or for extended slicing of the form `self[i:j:k]`, a slice object is created, and passed to `__delitem__()`, instead of `__delslice__()` being called.

Notice that these methods are only invoked when a single slice with a single colon is used, and the slice method is available. For slice operations involving extended slice notation, or in absence of the slice methods, `__getitem__()`, `__setitem__()` or `__delitem__()` is called with a slice object as argument.

The following example demonstrate how to make your program or module compatible with earlier versions of Python (assuming that methods `__getitem__()`, `__setitem__()` and `__delitem__()` support slice objects as arguments):

```
class MyClass:
    ...
    def __getitem__(self, index):
        ...
    def __setitem__(self, index, value):
        ...
    def __delitem__(self, index):
        ...

if sys.version_info < (2, 0):
    # They won't be defined if version is at least 2.0 final

    def __getslice__(self, i, j):
        return self[max(0, i):max(0, j):]
    def __setslice__(self, i, j, seq):
        self[max(0, i):max(0, j):] = seq
    def __delslice__(self, i, j):
        del self[max(0, i):max(0, j):]
    ...
```

Note the calls to `max()`; these are necessary because of the handling of negative indices before the `__*slice__()` methods are called. When negative indexes are used, the `__*item__()` methods receive them as provided, but the

`__*slice__()` methods get a “cooked” form of the index values. For each negative index value, the length of the sequence is added to the index before calling the method (which may still result in a negative index); this is the customary handling of negative indexes by the built-in sequence types, and the `__*item__()` methods are expected to do this as well. However, since they should already be doing that, negative indexes cannot be passed in; they must be constrained to the bounds of the sequence before being passed to the `__*item__()` methods. Calling `max(0, i)` conveniently returns the proper value.

### 3.4.8 Emulating numeric types

The following methods can be defined to emulate numeric objects. Methods corresponding to operations that are not supported by the particular kind of number implemented (e.g., bitwise operations for non-integral numbers) should be left undefined.

```
object.__add__(self, other)
object.__sub__(self, other)
object.__mul__(self, other)
object.__floordiv__(self, other)
object.__mod__(self, other)
object.__divmod__(self, other)
object.__pow__(self, other[, modulo])
object.__lshift__(self, other)
object.__rshift__(self, other)
object.__and__(self, other)
object.__xor__(self, other)
object.__or__(self, other)
```

These methods are called to implement the binary arithmetic operations (+, -, \*, //, %, `divmod()`, `pow()`, \*\*, <<, >>, &, ^, |). For instance, to evaluate the expression `x + y`, where `x` is an instance of a class that has an `__add__()` method, `x.__add__(y)` is called. The `__divmod__()` method should be the equivalent to using `__floordiv__()` and `__mod__()`; it should not be related to `__truediv__()` (described below). Note that `__pow__()` should be defined to accept an optional third argument if the ternary version of the built-in `pow()` function is to be supported.

If one of those methods does not support the operation with the supplied arguments, it should return `NotImplemented`.

```
object.__div__(self, other)
object.__truediv__(self, other)
```

The division operator (/) is implemented by these methods. The `__truediv__()` method is used when `__future__.division` is in effect, otherwise `__div__()` is used. If only one of these two methods is defined, the object will not support division in the alternate context; `TypeError` will be raised instead.

```
object.__radd__(self, other)
object.__rsub__(self, other)
object.__rmul__(self, other)
object.__rdiv__(self, other)
object.__rtruediv__(self, other)
object.__rfloordiv__(self, other)
object.__rmod__(self, other)
object.__rdivmod__(self, other)
object.__rpow__(self, other)
object.__rlshift__(self, other)
object.__rrshift__(self, other)
object.__rand__(self, other)
object.__rxor__(self, other)
```

object. `__ror__` (*self*, *other*)

These methods are called to implement the binary arithmetic operations (+, -, \*, /, %, `divmod()`, `pow()`, \*\*, <<, >>, &, ^, |) with reflected (swapped) operands. These functions are only called if the left operand does not support the corresponding operation and the operands are of different types.<sup>2</sup> For instance, to evaluate the expression `x - y`, where `y` is an instance of a class that has an `__rsub__()` method, `y.__rsub__(x)` is called if `x.__sub__(y)` returns *NotImplemented*.

Note that ternary `pow()` will not try calling `__rpow__()` (the coercion rules would become too complicated).

**Note:** If the right operand's type is a subclass of the left operand's type and that subclass provides the reflected method for the operation, this method will be called before the left operand's non-reflected method. This behavior allows subclasses to override their ancestors' operations.

object. `__iadd__` (*self*, *other*)

object. `__isub__` (*self*, *other*)

object. `__imul__` (*self*, *other*)

object. `__idiv__` (*self*, *other*)

object. `__itruediv__` (*self*, *other*)

object. `__ifloordiv__` (*self*, *other*)

object. `__imod__` (*self*, *other*)

object. `__ipow__` (*self*, *other*[, *modulo*])

object. `__ilshift__` (*self*, *other*)

object. `__irshift__` (*self*, *other*)

object. `__iand__` (*self*, *other*)

object. `__ixor__` (*self*, *other*)

object. `__ior__` (*self*, *other*)

These methods are called to implement the augmented arithmetic assignments (+=, -=, \*=, /=, //=, %=, \*\*=, <<=, >>=, &=, ^=, |=). These methods should attempt to do the operation in-place (modifying *self*) and return the result (which could be, but does not have to be, *self*). If a specific method is not defined, the augmented assignment falls back to the normal methods. For instance, to execute the statement `x += y`, where `x` is an instance of a class that has an `__iadd__()` method, `x.__iadd__(y)` is called. If `x` is an instance of a class that does not define a `__iadd__()` method, `x.__add__(y)` and `y.__radd__(x)` are considered, as with the evaluation of `x + y`.

object. `__neg__` (*self*)

object. `__pos__` (*self*)

object. `__abs__` (*self*)

object. `__invert__` (*self*)

Called to implement the unary arithmetic operations (-, +, `abs()` and ~).

object. `__complex__` (*self*)

object. `__int__` (*self*)

object. `__long__` (*self*)

object. `__float__` (*self*)

Called to implement the built-in functions `complex()`, `int()`, `long()`, and `float()`. Should return a value of the appropriate type.

object. `__oct__` (*self*)

object. `__hex__` (*self*)

Called to implement the built-in functions `oct()` and `hex()`. Should return a string value.

object. `__index__` (*self*)

Called to implement `operator.index()`. Also called whenever Python needs an integer object (such as in slicing). Must return an integer (int or long). New in version 2.5.

<sup>2</sup> For operands of the same type, it is assumed that if the non-reflected method (such as `__add__()`) fails the operation is not supported, which is why the reflected method is not called.

`object.__coerce__(self, other)`

Called to implement “mixed-mode” numeric arithmetic. Should either return a 2-tuple containing *self* and *other* converted to a common numeric type, or `None` if conversion is impossible. When the common type would be the type of *other*, it is sufficient to return `None`, since the interpreter will also ask the other object to attempt a coercion (but sometimes, if the implementation of the other type cannot be changed, it is useful to do the conversion to the other type here). A return value of `NotImplemented` is equivalent to returning `None`.

### 3.4.9 Coercion rules

This section used to document the rules for coercion. As the language has evolved, the coercion rules have become hard to document precisely; documenting what one version of one particular implementation does is undesirable. Instead, here are some informal guidelines regarding coercion. In Python 3, coercion will not be supported.

- If the left operand of a `%` operator is a string or Unicode object, no coercion takes place and the string formatting operation is invoked instead.
- It is no longer recommended to define a coercion operation. Mixed-mode operations on types that don’t define coercion pass the original arguments to the operation.
- New-style classes (those derived from `object`) never invoke the `__coerce__()` method in response to a binary operator; the only time `__coerce__()` is invoked is when the built-in function `coerce()` is called.
- For most intents and purposes, an operator that returns `NotImplemented` is treated the same as one that is not implemented at all.
- Below, `__op__()` and `__rop__()` are used to signify the generic method names corresponding to an operator; `__iop__()` is used for the corresponding in-place operator. For example, for the operator `+`, `__add__()` and `__radd__()` are used for the left and right variant of the binary operator, and `__iadd__()` for the in-place variant.
- For objects *x* and *y*, first `x.__op__(y)` is tried. If this is not implemented or returns `NotImplemented`, `y.__rop__(x)` is tried. If this is also not implemented or returns `NotImplemented`, a `TypeError` exception is raised. But see the following exception:
- Exception to the previous item: if the left operand is an instance of a built-in type or a new-style class, and the right operand is an instance of a proper subclass of that type or class and overrides the base’s `__rop__()` method, the right operand’s `__rop__()` method is tried *before* the left operand’s `__op__()` method.

This is done so that a subclass can completely override binary operators. Otherwise, the left operand’s `__op__()` method would always accept the right operand: when an instance of a given class is expected, an instance of a subclass of that class is always acceptable.

- When either operand type defines a coercion, this coercion is called before that type’s `__op__()` or `__rop__()` method is called, but no sooner. If the coercion returns an object of a different type for the operand whose coercion is invoked, part of the process is redone using the new object.
- When an in-place operator (like `+=`) is used, if the left operand implements `__iop__()`, it is invoked without any coercion. When the operation falls back to `__op__()` and/or `__rop__()`, the normal coercion rules apply.
- In `x + y`, if *x* is a sequence that implements sequence concatenation, sequence concatenation is invoked.
- In `x * y`, if one operand is a sequence that implements sequence repetition, and the other is an integer (`int` or `long`), sequence repetition is invoked.
- Rich comparisons (implemented by methods `__eq__()` and so on) never use coercion. Three-way comparison (implemented by `__cmp__()`) does use coercion under the same conditions as other binary operations use it.

- In the current implementation, the built-in numeric types `int`, `long`, `float`, and `complex` do not use coercion. All these types implement a `__coerce__()` method, for use by the built-in `coerce()` function. Changed in version 2.7.

### 3.4.10 With Statement Context Managers

New in version 2.5. A *context manager* is an object that defines the runtime context to be established when executing a `with` statement. The context manager handles the entry into, and the exit from, the desired runtime context for the execution of the block of code. Context managers are normally invoked using the `with` statement (described in section *The with statement*), but can also be used by directly invoking their methods.

Typical uses of context managers include saving and restoring various kinds of global state, locking and unlocking resources, closing opened files, etc.

For more information on context managers, see *typecontextmanager*.

`object.__enter__(self)`

Enter the runtime context related to this object. The `with` statement will bind this method's return value to the target(s) specified in the `as` clause of the statement, if any.

`object.__exit__(self, exc_type, exc_value, traceback)`

Exit the runtime context related to this object. The parameters describe the exception that caused the context to be exited. If the context was exited without an exception, all three arguments will be `None`.

If an exception is supplied, and the method wishes to suppress the exception (i.e., prevent it from being propagated), it should return a true value. Otherwise, the exception will be processed normally upon exit from this method.

Note that `__exit__()` methods should not reraise the passed-in exception; this is the caller's responsibility.

#### See Also:

**PEP 0343 - The “with” statement** The specification, background, and examples for the Python `with` statement.

### 3.4.11 Special method lookup for old-style classes

For old-style classes, special methods are always looked up in exactly the same way as any other method or attribute. This is the case regardless of whether the method is being looked up explicitly as in `x.__getitem__(i)` or implicitly as in `x[i]`.

This behaviour means that special methods may exhibit different behaviour for different instances of a single old-style class if the appropriate special attributes are set differently:

```
>>> class C:
...     pass
...
>>> c1 = C()
>>> c2 = C()
>>> c1.__len__ = lambda: 5
>>> c2.__len__ = lambda: 9
>>> len(c1)
5
>>> len(c2)
9
```

### 3.4.12 Special method lookup for new-style classes

For new-style classes, implicit invocations of special methods are only guaranteed to work correctly if defined on an object's type, not in the object's instance dictionary. That behaviour is the reason why the following code raises an exception (unlike the equivalent example with old-style classes):

```
>>> class C(object):
...     pass
...
>>> c = C()
>>> c.__len__ = lambda: 5
>>> len(c)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'C' has no len()
```

The rationale behind this behaviour lies with a number of special methods such as `__hash__()` and `__repr__()` that are implemented by all objects, including type objects. If the implicit lookup of these methods used the conventional lookup process, they would fail when invoked on the type object itself:

```
>>> 1.__hash__() == hash(1)
True
>>> int.__hash__() == hash(int)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor '__hash__' of 'int' object needs an argument
```

Incorrectly attempting to invoke an unbound method of a class in this way is sometimes referred to as 'metaclass confusion', and is avoided by bypassing the instance when looking up special methods:

```
>>> type(1).__hash__(1) == hash(1)
True
>>> type(int).__hash__(int) == hash(int)
True
```

In addition to bypassing any instance attributes in the interest of correctness, implicit special method lookup generally also bypasses the `__getattr__()` method even of the object's metaclass:

```
>>> class Meta(type):
...     def __getattr__(*args):
...         print "Metaclass getattr invoked"
...         return type.__getattr__(*args)
...
>>> class C(object):
...     __metaclass__ = Meta
...     def __len__(self):
...         return 10
...     def __getattr__(*args):
...         print "Class getattr invoked"
...         return object.__getattr__(*args)
...
>>> c = C()
>>> c.__len__()                                     # Explicit lookup via instance
Class getattr invoked
10
>>> type(c).__len__(c)                             # Explicit lookup via type
Metaclass getattr invoked
```

```
10
>>> len(c)                # Implicit lookup
10
```

Bypassing the `__getattr__()` machinery in this fashion provides significant scope for speed optimisations within the interpreter, at the cost of some flexibility in the handling of special methods (the special method *must* be set on the class object itself in order to be consistently invoked by the interpreter).



# EXECUTION MODEL

## 4.1 Naming and binding

*Names* refer to objects. Names are introduced by name binding operations. Each occurrence of a name in the program text refers to the *binding* of that name established in the innermost function block containing the use.

A *block* is a piece of Python program text that is executed as a unit. The following are blocks: a module, a function body, and a class definition. Each command typed interactively is a block. A script file (a file given as standard input to the interpreter or specified on the interpreter command line the first argument) is a code block. A script command (a command specified on the interpreter command line with the `-c` option) is a code block. The file read by the built-in function `execfile()` is a code block. The string argument passed to the built-in function `eval()` and to the `exec` statement is a code block. The expression read and evaluated by the built-in function `input()` is a code block.

A code block is executed in an *execution frame*. A frame contains some administrative information (used for debugging) and determines where and how execution continues after the code block's execution has completed.

A *scope* defines the visibility of a name within a block. If a local variable is defined in a block, its scope includes that block. If the definition occurs in a function block, the scope extends to any blocks contained within the defining one, unless a contained block introduces a different binding for the name. The scope of names defined in a class block is limited to the class block; it does not extend to the code blocks of methods – this includes generator expressions since they are implemented using a function scope. This means that the following will fail:

```
class A:
    a = 42
    b = list(a + i for i in range(10))
```

When a name is used in a code block, it is resolved using the nearest enclosing scope. The set of all such scopes visible to a code block is called the block's *environment*.

If a name is bound in a block, it is a local variable of that block. If a name is bound at the module level, it is a global variable. (The variables of the module code block are local and global.) If a variable is used in a code block but not defined there, it is a *free variable*.

When a name is not found at all, a `NameError` exception is raised. If the name refers to a local variable that has not been bound, a `UnboundLocalError` exception is raised. `UnboundLocalError` is a subclass of `NameError`.

The following constructs bind names: formal parameters to functions, `import` statements, class and function definitions (these bind the class or function name in the defining block), and targets that are identifiers if occurring in an assignment, `for` loop header, in the second position of an `except` clause header or after `as` in a `with` statement. The `import` statement of the form `from ... import *` binds all names defined in the imported module, except those beginning with an underscore. This form may only be used at the module level.

A target occurring in a `del` statement is also considered bound for this purpose (though the actual semantics are to unbind the name). It is illegal to unbind a name that is referenced by an enclosing scope; the compiler will report a `SyntaxError`.

Each assignment or import statement occurs within a block defined by a class or function definition or at the module level (the top-level code block).

If a name binding operation occurs anywhere within a code block, all uses of the name within the block are treated as references to the current block. This can lead to errors when a name is used within a block before it is bound. This rule is subtle. Python lacks declarations and allows name binding operations to occur anywhere within a code block. The local variables of a code block can be determined by scanning the entire text of the block for name binding operations.

If the global statement occurs within a block, all uses of the name specified in the statement refer to the binding of that name in the top-level namespace. Names are resolved in the top-level namespace by searching the global namespace, i.e. the namespace of the module containing the code block, and the builtins namespace, the namespace of the module `__builtin__`. The global namespace is searched first. If the name is not found there, the builtins namespace is searched. The global statement must precede all uses of the name.

The builtins namespace associated with the execution of a code block is actually found by looking up the name `__builtins__` in its global namespace; this should be a dictionary or a module (in the latter case the module's dictionary is used). By default, when in the `__main__` module, `__builtins__` is the built-in module `__builtin__` (note: no 's'); when in any other module, `__builtins__` is an alias for the dictionary of the `__builtin__` module itself. `__builtins__` can be set to a user-created dictionary to create a weak form of restricted execution.

**CPython implementation detail:** Users should not touch `__builtins__`; it is strictly an implementation detail. Users wanting to override values in the builtins namespace should `import` the `__builtin__` (no 's') module and modify its attributes appropriately.

The namespace for a module is automatically created the first time a module is imported. The main module for a script is always called `__main__`.

The `global` statement has the same scope as a name binding operation in the same block. If the nearest enclosing scope for a free variable contains a global statement, the free variable is treated as a global.

A class definition is an executable statement that may use and define names. These references follow the normal rules for name resolution. The namespace of the class definition becomes the attribute dictionary of the class. Names defined at the class scope are not visible in methods.

### 4.1.1 Interaction with dynamic features

There are several cases where Python statements are illegal when used in conjunction with nested scopes that contain free variables.

If a variable is referenced in an enclosing scope, it is illegal to delete the name. An error will be reported at compile time.

If the wild card form of import — `import *` — is used in a function and the function contains or is a nested block with free variables, the compiler will raise a `SyntaxError`.

If `exec` is used in a function and the function contains or is a nested block with free variables, the compiler will raise a `SyntaxError` unless the `exec` explicitly specifies the local namespace for the `exec`. (In other words, `exec obj` would be illegal, but `exec obj in ns` would be legal.)

The `eval()`, `execfile()`, and `input()` functions and the `exec` statement do not have access to the full environment for resolving names. Names may be resolved in the local and global namespaces of the caller. Free variables are not resolved in the nearest enclosing namespace, but in the global namespace.<sup>1</sup> The `exec` statement and the `eval()` and `execfile()` functions have optional arguments to override the global and local namespace. If only one namespace is specified, it is used for both.

---

<sup>1</sup> This limitation occurs because the code that is executed by these operations is not available at the time the module is compiled.

## 4.2 Exceptions

Exceptions are a means of breaking out of the normal flow of control of a code block in order to handle errors or other exceptional conditions. An exception is *raised* at the point where the error is detected; it may be *handled* by the surrounding code block or by any code block that directly or indirectly invoked the code block where the error occurred.

The Python interpreter raises an exception when it detects a run-time error (such as division by zero). A Python program can also explicitly raise an exception with the `raise` statement. Exception handlers are specified with the `try ... except` statement. The `finally` clause of such a statement can be used to specify cleanup code which does not handle the exception, but is executed whether an exception occurred or not in the preceding code.

Python uses the “termination” model of error handling: an exception handler can find out what happened and continue execution at an outer level, but it cannot repair the cause of the error and retry the failing operation (except by re-entering the offending piece of code from the top).

When an exception is not handled at all, the interpreter terminates execution of the program, or returns to its interactive main loop. In either case, it prints a stack backtrace, except when the exception is `SystemExit`.

Exceptions are identified by class instances. The `except` clause is selected depending on the class of the instance: it must reference the class of the instance or a base class thereof. The instance can be received by the handler and can carry additional information about the exceptional condition.

Exceptions can also be identified by strings, in which case the `except` clause is selected by object identity. An arbitrary value can be raised along with the identifying string which can be passed to the handler.

---

**Note:** Messages to exceptions are not part of the Python API. Their contents may change from one version of Python to the next without warning and should not be relied on by code which will run under multiple versions of the interpreter.

---

See also the description of the `try` statement in section *The try statement* and `raise` statement in section *The raise statement*.



# EXPRESSIONS

This chapter explains the meaning of the elements of expressions in Python.

**Syntax Notes:** In this and the following chapters, extended BNF notation will be used to describe syntax, not lexical analysis. When (one alternative of) a syntax rule has the form

```
name ::= othername
```

and no semantics are given, the semantics of this form of `name` are the same as for `othername`.

## 5.1 Arithmetic conversions

When a description of an arithmetic operator below uses the phrase “the numeric arguments are converted to a common type,” the arguments are coerced using the coercion rules listed at *Coercion rules*. If both arguments are standard numeric types, the following coercions are applied:

- If either argument is a complex number, the other is converted to complex;
- otherwise, if either argument is a floating point number, the other is converted to floating point;
- otherwise, if either argument is a long integer, the other is converted to long integer;
- otherwise, both must be plain integers and no conversion is necessary.

Some additional rules apply for certain operators (e.g., a string left argument to the ‘%’ operator). Extensions can define their own coercions.

## 5.2 Atoms

Atoms are the most basic elements of expressions. The simplest atoms are identifiers or literals. Forms enclosed in reverse quotes or in parentheses, brackets or braces are also categorized syntactically as atoms. The syntax for atoms is:

```
atom ::= identifier | literal | enclosure
enclosure ::= parenth_form | list_display
            | generator_expression | dict_display | set_display
            | string_conversion | yield_atom
```

### 5.2.1 Identifiers (Names)

An identifier occurring as an atom is a name. See section *Identifiers and keywords* for lexical definition and section *Naming and binding* for documentation of naming and binding.

When the name is bound to an object, evaluation of the atom yields that object. When a name is not bound, an attempt to evaluate it raises a `NameError` exception.

**Private name mangling:** When an identifier that textually occurs in a class definition begins with two or more underscore characters and does not end in two or more underscores, it is considered a *private name* of that class. Private names are transformed to a longer form before code is generated for them. The transformation inserts the class name in front of the name, with leading underscores removed, and a single underscore inserted in front of the class name. For example, the identifier `__spam` occurring in a class named `Ham` will be transformed to `_Ham__spam`. This transformation is independent of the syntactical context in which the identifier is used. If the transformed name is extremely long (longer than 255 characters), implementation defined truncation may happen. If the class name consists only of underscores, no transformation is done.

### 5.2.2 Literals

Python supports string literals and various numeric literals:

```
literal ::= stringliteral | integer | longinteger
         | floatnumber | imagnumber
```

Evaluation of a literal yields an object of the given type (string, integer, long integer, floating point number, complex number) with the given value. The value may be approximated in the case of floating point and imaginary (complex) literals. See section *Literals* for details.

All literals correspond to immutable data types, and hence the object's identity is less important than its value. Multiple evaluations of literals with the same value (either the same occurrence in the program text or a different occurrence) may obtain the same object or a different object with the same value.

### 5.2.3 Parenthesized forms

A parenthesized form is an optional expression list enclosed in parentheses:

```
parenth_form ::= "(" [expression_list] ")"
```

A parenthesized expression list yields whatever that expression list yields: if the list contains at least one comma, it yields a tuple; otherwise, it yields the single expression that makes up the expression list.

An empty pair of parentheses yields an empty tuple object. Since tuples are immutable, the rules for literals apply (i.e., two occurrences of the empty tuple may or may not yield the same object).

Note that tuples are not formed by the parentheses, but rather by use of the comma operator. The exception is the empty tuple, for which parentheses *are* required — allowing unparenthesized “nothing” in expressions would cause ambiguities and allow common typos to pass uncaught.

### 5.2.4 List displays

A list display is a possibly empty series of expressions enclosed in square brackets:

```

list_display      ::=  "[" [expression_list | list_comprehension] "]"
list_comprehension ::=  expression list_for
list_for          ::=  "for" target_list "in" old_expression_list [list_iter]
old_expression_list ::=  old_expression [(", " old_expression)+ [", "]]
old_expression    ::=  or_test | old_lambda_form
list_iter         ::=  list_for | list_if
list_if           ::=  "if" old_expression [list_iter]

```

A list display yields a new list object. Its contents are specified by providing either a list of expressions or a list comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and placed into the list object in that order. When a list comprehension is supplied, it consists of a single expression followed by at least one `for` clause and zero or more `for` or `if` clauses. In this case, the elements of the new list are those that would be produced by considering each of the `for` or `if` clauses a block, nesting from left to right, and evaluating the expression to produce a list element each time the innermost block is reached<sup>1</sup>.

## 5.2.5 Displays for sets and dictionaries

For constructing a set or a dictionary Python provides special syntax called “displays”, each of them in two flavors:

- either the container contents are listed explicitly, or
- they are computed via a set of looping and filtering instructions, called a *comprehension*.

Common syntax elements for comprehensions are:

```

comprehension    ::=  expression comp_for
comp_for         ::=  "for" target_list "in" or_test [comp_iter]
comp_iter        ::=  comp_for | comp_if
comp_if          ::=  "if" expression_nocond [comp_iter]

```

The comprehension consists of a single expression followed by at least one `for` clause and zero or more `for` or `if` clauses. In this case, the elements of the new container are those that would be produced by considering each of the `for` or `if` clauses a block, nesting from left to right, and evaluating the expression to produce an element each time the innermost block is reached.

Note that the comprehension is executed in a separate scope, so names assigned to in the target list don’t “leak” in the enclosing scope.

## 5.2.6 Generator expressions

A generator expression is a compact generator notation in parentheses:

```

generator_expression ::=  "(" expression comp_for ")"

```

A generator expression yields a new generator object. Its syntax is the same as for comprehensions, except that it is enclosed in parentheses instead of brackets or curly braces.

Variables used in the generator expression are evaluated lazily when the `__next__()` method is called for generator object (in the same fashion as normal generators). However, the leftmost `for` clause is immediately evaluated, so that an error produced by it can be seen before any other possible error in the code that handles the generator expression. Subsequent `for` clauses cannot be evaluated immediately since they may depend on the previous `for` loop. For example: `(x*y for x in range(10) for y in bar(x))`.

<sup>1</sup> In Python 2.3 and later releases, a list comprehension “leaks” the control variables of each `for` it contains into the containing scope. However, this behavior is deprecated, and relying on it will not work in Python 3.

The parentheses can be omitted on calls with only one argument. See section *Calls* for the detail.

## 5.2.7 Dictionary displays

A dictionary display is a possibly empty series of key/datum pairs enclosed in curly braces:

```
dict_display      ::=  "{" [key_datum_list | dict_comprehension] "}"
key_datum_list   ::=  key_datum ("," key_datum)* [","]
key_datum        ::=  expression ":" expression
dict_comprehension ::=  expression ":" expression comp_for
```

A dictionary display yields a new dictionary object.

If a comma-separated sequence of key/datum pairs is given, they are evaluated from left to right to define the entries of the dictionary: each key object is used as a key into the dictionary to store the corresponding datum. This means that you can specify the same key multiple times in the key/datum list, and the final dictionary's value for that key will be the last one given.

A dict comprehension, in contrast to list and set comprehensions, needs two expressions separated with a colon followed by the usual “for” and “if” clauses. When the comprehension is run, the resulting key and value elements are inserted in the new dictionary in the order they are produced.

Restrictions on the types of the key values are listed earlier in section *The standard type hierarchy*. (To summarize, the key type should be *hashable*, which excludes all mutable objects.) Clashes between duplicate keys are not detected; the last datum (textually rightmost in the display) stored for a given key value prevails.

## 5.2.8 Set displays

A set display is denoted by curly braces and distinguishable from dictionary displays by the lack of colons separating keys and values:

```
set_display ::=  "{" (expression_list | comprehension) "}"
```

A set display yields a new mutable set object, the contents being specified by either a sequence of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and added to the set object. When a comprehension is supplied, the set is constructed from the elements resulting from the comprehension.

An empty set cannot be constructed with `{}`; this literal constructs an empty dictionary.

## 5.2.9 String conversions

A string conversion is an expression list enclosed in reverse (a.k.a. backward) quotes:

```
string_conversion ::=  """ expression_list """
```

A string conversion evaluates the contained expression list and converts the resulting object into a string according to rules specific to its type.

If the object is a string, a number, `None`, or a tuple, list or dictionary containing only objects whose type is one of these, the resulting string is a valid Python expression which can be passed to the built-in function `eval()` to yield an expression with the same value (or an approximation, if floating point numbers are involved).

(In particular, converting a string adds quotes around it and converts “funny” characters to escape sequences that are safe to print.)

Recursive objects (for example, lists or dictionaries that contain a reference to themselves, directly or indirectly) use `...` to indicate a recursive reference, and the result cannot be passed to `eval()` to get an equal value (`SyntaxError` will be raised instead).

The built-in function `repr()` performs exactly the same conversion in its argument as enclosing it in parentheses and reverse quotes does. The built-in function `str()` performs a similar but more user-friendly conversion.

## 5.2.10 Yield expressions

```
yield_atom      ::= "(" yield_expression ")"
yield_expression ::= "yield" [expression_list]
```

New in version 2.5. The `yield` expression is only used when defining a generator function, and can only be used in the body of a function definition. Using a `yield` expression in a function definition is sufficient to cause that definition to create a generator function instead of a normal function.

When a generator function is called, it returns an iterator known as a generator. That generator then controls the execution of a generator function. The execution starts when one of the generator's methods is called. At that time, the execution proceeds to the first `yield` expression, where it is suspended again, returning the value of `expression_list` to generator's caller. By suspended we mean that all local state is retained, including the current bindings of local variables, the instruction pointer, and the internal evaluation stack. When the execution is resumed by calling one of the generator's methods, the function can proceed exactly as if the `yield` expression was just another external call. The value of the `yield` expression after resuming depends on the method which resumed the execution.

All of this makes generator functions quite similar to coroutines; they yield multiple times, they have more than one entry point and their execution can be suspended. The only difference is that a generator function cannot control where should the execution continue after it yields; the control is always transferred to the generator's caller.

### Generator-iterator methods

This subsection describes the methods of a generator iterator. They can be used to control the execution of a generator function.

Note that calling any of the generator methods below when the generator is already executing raises a `ValueError` exception.

`generator.next()`

Starts the execution of a generator function or resumes it at the last executed `yield` expression. When a generator function is resumed with a `next()` method, the current `yield` expression always evaluates to `None`. The execution then continues to the next `yield` expression, where the generator is suspended again, and the value of the `expression_list` is returned to `next()`'s caller. If the generator exits without yielding another value, a `StopIteration` exception is raised.

`generator.send(value)`

Resumes the execution and "sends" a value into the generator function. The `value` argument becomes the result of the current `yield` expression. The `send()` method returns the next value yielded by the generator, or raises `StopIteration` if the generator exits without yielding another value. When `send()` is called to start the generator, it must be called with `None` as the argument, because there is no `yield` expression that could receive the value.

`generator.throw(type[, value[, traceback]])`

Raises an exception of type `type` at the point where generator was paused, and returns the next value yielded by the generator function. If the generator exits without yielding another value, a `StopIteration` exception is raised. If the generator function does not catch the passed-in exception, or raises a different exception, then that exception propagates to the caller.

`generator.close()`

Raises a `GeneratorExit` at the point where the generator function was paused. If the generator function then raises `StopIteration` (by exiting normally, or due to already being closed) or `GeneratorExit` (by not catching the exception), `close` returns to its caller. If the generator yields a value, a `RuntimeError` is raised. If the generator raises any other exception, it is propagated to the caller. `close()` does nothing if the generator has already exited due to an exception or normal exit.

Here is a simple example that demonstrates the behavior of generators and generator functions:

```
>>> def echo(value=None):
...     print "Execution starts when 'next()' is called for the first time."
...     try:
...         while True:
...             try:
...                 value = (yield value)
...             except Exception, e:
...                 value = e
...     finally:
...         print "Don't forget to clean up when 'close()' is called."
...
>>> generator = echo(1)
>>> print generator.next()
Execution starts when 'next()' is called for the first time.
1
>>> print generator.next()
None
>>> print generator.send(2)
2
>>> generator.throw(TypeError, "spam")
TypeError('spam',)
>>> generator.close()
Don't forget to clean up when 'close()' is called.
```

**See Also:**

**PEP 0342 - Coroutines via Enhanced Generators** The proposal to enhance the API and syntax of generators, making them usable as simple coroutines.

## 5.3 Primaries

Primaries represent the most tightly bound operations of the language. Their syntax is:

```
primary ::= atom | attributeref | subscription | slicing | call
```

### 5.3.1 Attribute references

An attribute reference is a primary followed by a period and a name:

```
attributeref ::= primary "." identifier
```

The primary must evaluate to an object of a type that supports attribute references, e.g., a module, list, or an instance. This object is then asked to produce the attribute whose name is the identifier. If this attribute is not available, the

exception `AttributeError` is raised. Otherwise, the type and value of the object produced is determined by the object. Multiple evaluations of the same attribute reference may yield different objects.

### 5.3.2 Subscriptions

A subscription selects an item of a sequence (string, tuple or list) or mapping (dictionary) object:

```
subscription ::= primary "[" expression_list "]"
```

The primary must evaluate to an object of a sequence or mapping type.

If the primary is a mapping, the expression list must evaluate to an object whose value is one of the keys of the mapping, and the subscription selects the value in the mapping that corresponds to that key. (The expression list is a tuple except if it has exactly one item.)

If the primary is a sequence, the expression (list) must evaluate to a plain integer. If this value is negative, the length of the sequence is added to it (so that, e.g., `x[-1]` selects the last item of `x`.) The resulting value must be a nonnegative integer less than the number of items in the sequence, and the subscription selects the item whose index is that value (counting from zero).

A string's items are characters. A character is not a separate data type but a string of exactly one character.

### 5.3.3 Slicings

A slicing selects a range of items in a sequence object (e.g., a string, tuple or list). Slicings may be used as expressions or as targets in assignment or `del` statements. The syntax for a slicing:

```
slicing          ::= simple_slicing | extended_slicing
simple_slicing    ::= primary "[" short_slice "]"
extended_slicing ::= primary "[" slice_list "]"
slice_list       ::= slice_item ("," slice_item)* [","]
slice_item       ::= expression | proper_slice | ellipsis
proper_slice     ::= short_slice | long_slice
short_slice      ::= [lower_bound] ":" [upper_bound]
long_slice       ::= short_slice ":" [stride]
lower_bound      ::= expression
upper_bound      ::= expression
stride           ::= expression
ellipsis         ::= "..."
```

There is ambiguity in the formal syntax here: anything that looks like an expression list also looks like a slice list, so any subscription can be interpreted as a slicing. Rather than further complicating the syntax, this is disambiguated by defining that in this case the interpretation as a subscription takes priority over the interpretation as a slicing (this is the case if the slice list contains no proper slice nor ellipses). Similarly, when the slice list has exactly one short slice and no trailing comma, the interpretation as a simple slicing takes priority over that as an extended slicing.

The semantics for a simple slicing are as follows. The primary must evaluate to a sequence object. The lower and upper bound expressions, if present, must evaluate to plain integers; defaults are zero and the `sys.maxint`, respectively. If either bound is negative, the sequence's length is added to it. The slicing now selects all items with index  $k$  such that  $i \leq k < j$  where  $i$  and  $j$  are the specified lower and upper bounds. This may be an empty sequence. It is not an error if  $i$  or  $j$  lie outside the range of valid indexes (such items don't exist so they aren't selected).

The semantics for an extended slicing are as follows. The primary must evaluate to a mapping object, and it is indexed with a key that is constructed from the slice list, as follows. If the slice list contains at least one comma, the key is a tuple containing the conversion of the slice items; otherwise, the conversion of the lone slice item is the key. The

conversion of a slice item that is an expression is that expression. The conversion of an ellipsis slice item is the built-in `Ellipsis` object. The conversion of a proper slice is a slice object (see section *The standard type hierarchy*) whose `start`, `stop` and `step` attributes are the values of the expressions given as lower bound, upper bound and stride, respectively, substituting `None` for missing expressions.

### 5.3.4 Calls

A call calls a callable object (e.g., a function) with a possibly empty series of arguments:

```

call ::= primary "(" [argument_list [","]]
      | expression genexpr_for ")"
argument_list ::= positional_arguments [","] keyword_arguments
               ["**" expression] ["**" expression]
               | keyword_arguments [","] "*" expression
               ["**" expression]
               | "*" expression [","] "*" expression [","] "*" expression
               | "*" expression
positional_arguments ::= expression ("," expression)*
keyword_arguments ::= keyword_item ("," keyword_item)*
keyword_item ::= identifier "=" expression
    
```

A trailing comma may be present after the positional and keyword arguments but does not affect the semantics.

The primary must evaluate to a callable object (user-defined functions, built-in functions, methods of built-in objects, class objects, methods of class instances, and certain class instances themselves are callable; extensions may define additional callable object types). All argument expressions are evaluated before the call is attempted. Please refer to section *Function definitions* for the syntax of formal parameter lists.

If keyword arguments are present, they are first converted to positional arguments, as follows. First, a list of unfilled slots is created for the formal parameters. If there are  $N$  positional arguments, they are placed in the first  $N$  slots. Next, for each keyword argument, the identifier is used to determine the corresponding slot (if the identifier is the same as the first formal parameter name, the first slot is used, and so on). If the slot is already filled, a `TypeError` exception is raised. Otherwise, the value of the argument is placed in the slot, filling it (even if the expression is `None`, it fills the slot). When all arguments have been processed, the slots that are still unfilled are filled with the corresponding default value from the function definition. (Default values are calculated, once, when the function is defined; thus, a mutable object such as a list or dictionary used as default value will be shared by all calls that don't specify an argument value for the corresponding slot; this should usually be avoided.) If there are any unfilled slots for which no default value is specified, a `TypeError` exception is raised. Otherwise, the list of filled slots is used as the argument list for the call.

**CPython implementation detail:** An implementation may provide built-in functions whose positional parameters do not have names, even if they are 'named' for the purpose of documentation, and which therefore cannot be supplied by keyword. In CPython, this is the case for functions implemented in C that use `PyArg_ParseTuple()` to parse their arguments.

If there are more positional arguments than there are formal parameter slots, a `TypeError` exception is raised, unless a formal parameter using the syntax `*identifier` is present; in this case, that formal parameter receives a tuple containing the excess positional arguments (or an empty tuple if there were no excess positional arguments).

If any keyword argument does not correspond to a formal parameter name, a `TypeError` exception is raised, unless a formal parameter using the syntax `**identifier` is present; in this case, that formal parameter receives a dictionary containing the excess keyword arguments (using the keywords as keys and the argument values as corresponding values), or a (new) empty dictionary if there were no excess keyword arguments.

If the syntax `*expression` appears in the function call, `expression` must evaluate to an iterable. Elements from this iterable are treated as if they were additional positional arguments; if there are positional arguments  $x_1, \dots, x_N$ ,

and `expression` evaluates to a sequence  $y_1, \dots, y_M$ , this is equivalent to a call with  $M+N$  positional arguments  $x_1, \dots, x_N, y_1, \dots, y_M$ .

A consequence of this is that although the `*expression` syntax may appear *after* some keyword arguments, it is processed *before* the keyword arguments (and the `**expression` argument, if any – see below). So:

```
>>> def f(a, b):
...     print a, b
...
>>> f(b=1, *(2,))
2 1
>>> f(a=1, *(2,))
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: f() got multiple values for keyword argument 'a'
>>> f(1, *(2,))
1 2
```

It is unusual for both keyword arguments and the `*expression` syntax to be used in the same call, so in practice this confusion does not arise.

If the syntax `**expression` appears in the function call, `expression` must evaluate to a mapping, the contents of which are treated as additional keyword arguments. In the case of a keyword appearing in both `expression` and as an explicit keyword argument, a `TypeError` exception is raised.

Formal parameters using the syntax `*identifier` or `**identifier` cannot be used as positional argument slots or as keyword argument names. Formal parameters using the syntax `(sublist)` cannot be used as keyword argument names; the outermost sublist corresponds to a single unnamed argument slot, and the argument value is assigned to the sublist using the usual tuple assignment rules after all other parameter processing is done.

A call always returns some value, possibly `None`, unless it raises an exception. How this value is computed depends on the type of the callable object.

If it is—

- a user-defined function:** The code block for the function is executed, passing it the argument list. The first thing the code block will do is bind the formal parameters to the arguments; this is described in section [Function definitions](#). When the code block executes a `return` statement, this specifies the return value of the function call.
- a built-in function or method:** The result is up to the interpreter; see *built-in-funcs* for the descriptions of built-in functions and methods.
- a class object:** A new instance of that class is returned.
- a class instance method:** The corresponding user-defined function is called, with an argument list that is one longer than the argument list of the call: the instance becomes the first argument.
- a class instance:** The class must define a `__call__()` method; the effect is then the same as if that method was called.

## 5.4 The power operator

The power operator binds more tightly than unary operators on its left; it binds less tightly than unary operators on its right. The syntax is:

```
power ::= primary ["**" u_expr]
```

Thus, in an unparenthesized sequence of power and unary operators, the operators are evaluated from right to left (this does not constrain the evaluation order for the operands): `-1**2` results in `-1`.

The power operator has the same semantics as the built-in `pow()` function, when called with two arguments: it yields its left argument raised to the power of its right argument. The numeric arguments are first converted to a common type. The result type is that of the arguments after coercion.

With mixed operand types, the coercion rules for binary arithmetic operators apply. For int and long int operands, the result has the same type as the operands (after coercion) unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, `10**2` returns `100`, but `10**-2` returns `0.01`. (This last feature was added in Python 2.2. In Python 2.1 and before, if both arguments were of integer types and the second argument was negative, an exception was raised).

Raising `0.0` to a negative power results in a `ZeroDivisionError`. Raising a negative number to a fractional power results in a `ValueError`.

## 5.5 Unary arithmetic and bitwise operations

All unary arithmetic and bitwise operations have the same priority:

```
u_expr ::= power | "-" u_expr | "+" u_expr | "~" u_expr
```

The unary `-` (minus) operator yields the negation of its numeric argument.

The unary `+` (plus) operator yields its numeric argument unchanged.

The unary `~` (invert) operator yields the bitwise inversion of its plain or long integer argument. The bitwise inversion of `x` is defined as `-(x+1)`. It only applies to integral numbers.

In all three cases, if the argument does not have the proper type, a `TypeError` exception is raised.

## 5.6 Binary arithmetic operations

The binary arithmetic operations have the conventional priority levels. Note that some of these operations also apply to certain non-numeric types. Apart from the power operator, there are only two levels, one for multiplicative operators and one for additive operators:

```
m_expr ::= u_expr | m_expr "*" u_expr | m_expr "/" u_expr | m_expr "//" u_expr | m_expr "/" u_expr
          | m_expr "%" u_expr
a_expr ::= m_expr | a_expr "+" m_expr | a_expr "-" m_expr
```

The `*` (multiplication) operator yields the product of its arguments. The arguments must either both be numbers, or one argument must be an integer (plain or long) and the other must be a sequence. In the former case, the numbers are converted to a common type and then multiplied together. In the latter case, sequence repetition is performed; a negative repetition factor yields an empty sequence.

The `/` (division) and `//` (floor division) operators yield the quotient of their arguments. The numeric arguments are first converted to a common type. Plain or long integer division yields an integer of the same type; the result is that of mathematical division with the ‘floor’ function applied to the result. Division by zero raises the `ZeroDivisionError` exception.

The `%` (modulo) operator yields the remainder from the division of the first argument by the second. The numeric arguments are first converted to a common type. A zero right argument raises the `ZeroDivisionError` exception. The arguments may be floating point numbers, e.g., `3.14%0.7` equals `0.34` (since `3.14` equals `4*0.7 + 0.34`).

The modulo operator always yields a result with the same sign as its second operand (or zero); the absolute value of the result is strictly smaller than the absolute value of the second operand <sup>2</sup>.

The integer division and modulo operators are connected by the following identity:  $x == (x/y) * y + (x \% y)$ . Integer division and modulo are also connected with the built-in function `divmod()`: `divmod(x, y) == (x/y, x%y)`. These identities don't hold for floating point numbers; there similar identities hold approximately where  $x/y$  is replaced by `floor(x/y)` or `floor(x/y) - 1` <sup>3</sup>.

In addition to performing the modulo operation on numbers, the `%` operator is also overloaded by string and unicode objects to perform string formatting (also known as interpolation). The syntax for string formatting is described in the Python Library Reference, section *string-formatting*. Deprecated since version 2.3: The floor division operator, the modulo operator, and the `divmod()` function are no longer defined for complex numbers. Instead, convert to a floating point number using the `abs()` function if appropriate. The `+` (addition) operator yields the sum of its arguments. The arguments must either both be numbers or both sequences of the same type. In the former case, the numbers are converted to a common type and then added together. In the latter case, the sequences are concatenated.

The `-` (subtraction) operator yields the difference of its arguments. The numeric arguments are first converted to a common type.

## 5.7 Shifting operations

The shifting operations have lower priority than the arithmetic operations:

```
shift_expr ::= a_expr | shift_expr ( "<<" | ">>" ) a_expr
```

These operators accept plain or long integers as arguments. The arguments are converted to a common type. They shift the first argument to the left or right by the number of bits given by the second argument.

A right shift by  $n$  bits is defined as division by `pow(2, n)`. A left shift by  $n$  bits is defined as multiplication with `pow(2, n)`. Negative shift counts raise a `ValueError` exception.

---

**Note:** In the current implementation, the right-hand operand is required to be at most `sys.maxsize`. If the right-hand operand is larger than `sys.maxsize` an `OverflowError` exception is raised.

---

## 5.8 Binary bitwise operations

Each of the three bitwise operations has a different priority level:

```
and_expr  ::= shift_expr | and_expr "&" shift_expr
xor_expr  ::= and_expr | xor_expr "^" and_expr
or_expr   ::= xor_expr | or_expr "|" xor_expr
```

The `&` operator yields the bitwise AND of its arguments, which must be plain or long integers. The arguments are converted to a common type.

---

<sup>2</sup> While  $\text{abs}(x \% y) < \text{abs}(y)$  is true mathematically, for floats it may not be true numerically due to roundoff. For example, and assuming a platform on which a Python float is an IEEE 754 double-precision number, in order that `-1e-100 % 1e100` have the same sign as `1e100`, the computed result is `-1e-100 + 1e100`, which is numerically exactly equal to `1e100`. The function `math.fmod()` returns a result whose sign matches the sign of the first argument instead, and so returns `-1e-100` in this case. Which approach is more appropriate depends on the application.

<sup>3</sup> If  $x$  is very close to an exact integer multiple of  $y$ , it's possible for `floor(x/y)` to be one larger than  $(x - x \% y) / y$  due to rounding. In such cases, Python returns the latter result, in order to preserve that `divmod(x, y)[0] * y + x % y` be very close to  $x$ .

The `^` operator yields the bitwise XOR (exclusive OR) of its arguments, which must be plain or long integers. The arguments are converted to a common type.

The `|` operator yields the bitwise (inclusive) OR of its arguments, which must be plain or long integers. The arguments are converted to a common type.

## 5.9 Comparisons

Unlike C, all comparison operations in Python have the same priority, which is lower than that of any arithmetic, shifting or bitwise operation. Also unlike C, expressions like `a < b < c` have the interpretation that is conventional in mathematics:

```
comparison ::= or_expr ( comp_operator or_expr ) *
comp_operator ::= "<" | ">" | "==" | ">=" | "<=" | "<>" | "!="
               | "is" ["not"] | ["not"] "in"
```

Comparisons yield boolean values: True or False.

Comparisons can be chained arbitrarily, e.g., `x < y <= z` is equivalent to `x < y` and `y <= z`, except that `y` is evaluated only once (but in both cases `z` is not evaluated at all when `x < y` is found to be false).

Formally, if `a, b, c, ..., y, z` are expressions and `op1, op2, ..., opN` are comparison operators, then `a op1 b op2 c ... y opN z` is equivalent to `a op1 b` and `b op2 c` and `... y opN z`, except that each expression is evaluated at most once.

Note that `a op1 b op2 c` doesn't imply any kind of comparison between `a` and `c`, so that, e.g., `x < y > z` is perfectly legal (though perhaps not pretty).

The forms `<>` and `!=` are equivalent; for consistency with C, `!=` is preferred; where `!=` is mentioned below `<>` is also accepted. The `<>` spelling is considered obsolescent.

The operators `<`, `>`, `==`, `>=`, `<=`, and `!=` compare the values of two objects. The objects need not have the same type. If both are numbers, they are converted to a common type. Otherwise, objects of different types *always* compare unequal, and are ordered consistently but arbitrarily. You can control comparison behavior of objects of non-built-in types by defining a `__cmp__` method or rich comparison methods like `__gt__`, described in section *Special method names*.

(This unusual definition of comparison was used to simplify the definition of operations like sorting and the `in` and `not in` operators. In the future, the comparison rules for objects of different types are likely to change.)

Comparison of objects of the same type depends on the type:

- Numbers are compared arithmetically.
- Strings are compared lexicographically using the numeric equivalents (the result of the built-in function `ord()`) of their characters. Unicode and 8-bit strings are fully interoperable in this behavior.<sup>4</sup>
- Tuples and lists are compared lexicographically using comparison of corresponding elements. This means that to compare equal, each element must compare equal and the two sequences must be of the same type and have the same length.

If not equal, the sequences are ordered the same as their first differing elements. For example, `cmp([1, 2, x], [1, 2, y])` returns the same as `cmp(x, y)`. If the corresponding element does not exist, the shorter sequence is ordered first (for example, `[1, 2] < [1, 2, 3]`).

<sup>4</sup> While comparisons between unicode strings make sense at the byte level, they may be counter-intuitive to users. For example, the strings `u"\u00c7"` and `u"\u0043\u0327"` compare differently, even though they both represent the same unicode character (LATIN CAPITAL LETTER C WITH CEDILLA). To compare strings in a human recognizable way, compare using `unicodedata.normalize()`.

- Mappings (dictionaries) compare equal if and only if their sorted (key, value) lists compare equal.<sup>5</sup> Outcomes other than equality are resolved consistently, but are not otherwise defined.<sup>6</sup>
- Most other objects of built-in types compare unequal unless they are the same object; the choice whether one object is considered smaller or larger than another one is made arbitrarily but consistently within one execution of a program.

The operators `in` and `not in` test for collection membership. `x in s` evaluates to true if `x` is a member of the collection `s`, and false otherwise. `x not in s` returns the negation of `x in s`. The collection membership test has traditionally been bound to sequences; an object is a member of a collection if the collection is a sequence and contains an element equal to that object. However, it make sense for many other object types to support membership tests without being a sequence. In particular, dictionaries (for keys) and sets support membership testing.

For the list and tuple types, `x in y` is true if and only if there exists an index `i` such that `x == y[i]` is true.

For the Unicode and string types, `x in y` is true if and only if `x` is a substring of `y`. An equivalent test is `y.find(x) != -1`. Note, `x` and `y` need not be the same type; consequently, `u'ab' in 'abc'` will return `True`. Empty strings are always considered to be a substring of any other string, so `"" in "abc"` will return `True`. Changed in version 2.3: Previously, `x` was required to be a string of length 1. For user-defined classes which define the `__contains__()` method, `x in y` is true if and only if `y.__contains__(x)` is true.

For user-defined classes which do not define `__contains__()` but do define `__iter__()`, `x in y` is true if some value `z` with `x == z` is produced while iterating over `y`. If an exception is raised during the iteration, it is as if `in` raised that exception.

Lastly, the old-style iteration protocol is tried: if a class defines `__getitem__()`, `x in y` is true if and only if there is a non-negative integer index `i` such that `x == y[i]`, and all lower integer indices do not raise `IndexError` exception. (If any other exception is raised, it is as if `in` raised that exception).

The operator `not in` is defined to have the inverse true value of `in`.

The operators `is` and `is not` test for object identity: `x is y` is true if and only if `x` and `y` are the same object. `x is not y` yields the inverse truth value.<sup>7</sup>

## 5.10 Boolean operations

```
or_test    ::=  and_test | or_test "or" and_test
and_test   ::=  not_test | and_test "and" not_test
not_test   ::=  comparison | "not" not_test
```

In the context of Boolean operations, and also when expressions are used by control flow statements, the following values are interpreted as false: `False`, `None`, numeric zero of all types, and empty strings and containers (including strings, tuples, lists, dictionaries, sets and frozensets). All other values are interpreted as true. (See the `__nonzero__()` special method for a way to change this.)

The operator `not` yields `True` if its argument is false, `False` otherwise.

The expression `x and y` first evaluates `x`; if `x` is false, its value is returned; otherwise, `y` is evaluated and the resulting value is returned.

The expression `x or y` first evaluates `x`; if `x` is true, its value is returned; otherwise, `y` is evaluated and the resulting value is returned.

<sup>5</sup> The implementation computes this efficiently, without constructing lists or sorting.

<sup>6</sup> Earlier versions of Python used lexicographic comparison of the sorted (key, value) lists, but this was very expensive for the common case of comparing for equality. An even earlier version of Python compared dictionaries by identity only, but this caused surprises because people expected to be able to test a dictionary for emptiness by comparing it to `{}`.

<sup>7</sup> Due to automatic garbage-collection, free lists, and the dynamic nature of descriptors, you may notice seemingly unusual behaviour in certain uses of the `is` operator, like those involving comparisons between instance methods, or constants. Check their documentation for more info.

(Note that neither `and` nor `or` restrict the value and type they return to `False` and `True`, but rather return the last evaluated argument. This is sometimes useful, e.g., if `s` is a string that should be replaced by a default value if it is empty, the expression `s or 'foo'` yields the desired value. Because `not` has to invent a value anyway, it does not bother to return a value of the same type as its argument, so e.g., `not 'foo'` yields `False`, not `''`.)

## 5.11 Conditional Expressions

New in version 2.5.

```
conditional_expression ::= or_test ["if" or_test "else" expression]
expression              ::= conditional_expression | lambda_form
```

Conditional expressions (sometimes called a “ternary operator”) have the lowest priority of all Python operations.

The expression `x if C else y` first evaluates the condition, `C` (*not* `x`); if `C` is true, `x` is evaluated and its value is returned; otherwise, `y` is evaluated and its value is returned.

See [PEP 308](#) for more details about conditional expressions.

## 5.12 Lambdas

```
lambda_form          ::= "lambda" [parameter_list]: expression
old_lambda_form      ::= "lambda" [parameter_list]: old_expression
```

Lambda forms (lambda expressions) have the same syntactic position as expressions. They are a shorthand to create anonymous functions; the expression `lambda arguments: expression` yields a function object. The unnamed object behaves like a function object defined with

```
def name(arguments):
    return expression
```

See section *Function definitions* for the syntax of parameter lists. Note that functions created with lambda forms cannot contain statements.

## 5.13 Expression lists

```
expression_list ::= expression ( "," expression )* [","]
```

An expression list containing at least one comma yields a tuple. The length of the tuple is the number of expressions in the list. The expressions are evaluated from left to right.

The trailing comma is required only to create a single tuple (a.k.a. a *singleton*); it is optional in all other cases. A single expression without a trailing comma doesn’t create a tuple, but rather yields the value of that expression. (To create an empty tuple, use an empty pair of parentheses: `()`.)

## 5.14 Evaluation order

Python evaluates expressions from left to right. Notice that while evaluating an assignment, the right-hand side is evaluated before the left-hand side.

In the following lines, expressions will be evaluated in the arithmetic order of their suffixes:

```
expr1, expr2, expr3, expr4
(expr1, expr2, expr3, expr4)
{expr1: expr2, expr3: expr4}
expr1 + expr2 * (expr3 - expr4)
expr1(expr2, expr3, *expr4, **expr5)
expr3, expr4 = expr1, expr2
```

## 5.15 Summary

The following table summarizes the operator precedences in Python, from lowest precedence (least binding) to highest precedence (most binding). Operators in the same box have the same precedence. Unless the syntax is explicitly given, operators are binary. Operators in the same box group left to right (except for comparisons, including tests, which all have the same precedence and chain from left to right — see section *Comparisons* — and exponentiation, which groups from right to left).

Operator	Description
<code>lambda</code>	Lambda expression
<code>if - else</code>	Conditional expression
<code>or</code>	Boolean OR
<code>and</code>	Boolean AND
<code>not x</code>	Boolean NOT
<code>in, not in, is, is not, &lt;, &lt;=, &gt;, &gt;=, &lt;&gt;, !=, ==</code>	Comparisons, including membership tests and identity tests,
<code> </code>	Bitwise OR
<code>^</code>	Bitwise XOR
<code>&amp;</code>	Bitwise AND
<code>&lt;&lt;, &gt;&gt;</code>	Shifts
<code>+, -</code>	Addition and subtraction
<code>*, /, //, %</code>	Multiplication, division, remainder <sup>8</sup>
<code>+x, -x, ~x</code>	Positive, negative, bitwise NOT
<code>**</code>	Exponentiation <sup>9</sup>
<code>x[index], x[index:index], x(arguments...), x.attribute (expressions...), [expressions...], {key:datum...}, `expressions...`</code>	Subscription, slicing, call, attribute reference  Binding or tuple display, list display, dictionary display, string conversion

<sup>8</sup>The % operator is also used for string formatting; the same precedence applies.

<sup>9</sup>The power operator \*\* binds less tightly than an arithmetic or bitwise unary operator on its right, that is, `2**~1` is `0.5`.



# SIMPLE STATEMENTS

Simple statements are comprised within a single logical line. Several simple statements may occur on a single line separated by semicolons. The syntax for simple statements is:

```
simple_stmt ::= expression_stmt
            | assert_stmt
            | assignment_stmt
            | augmented_assignment_stmt
            | pass_stmt
            | del_stmt
            | print_stmt
            | return_stmt
            | yield_stmt
            | raise_stmt
            | break_stmt
            | continue_stmt
            | import_stmt
            | global_stmt
            | exec_stmt
```

## 6.1 Expression statements

Expression statements are used (mostly interactively) to compute and write a value, or (usually) to call a procedure (a function that returns no meaningful result; in Python, procedures return the value `None`). Other uses of expression statements are allowed and occasionally useful. The syntax for an expression statement is:

```
expression_stmt ::= expression_list
```

An expression statement evaluates the expression list (which may be a single expression).

In interactive mode, if the value is not `None`, it is converted to a string using the built-in `repr()` function and the resulting string is written to standard output (see section *The print statement*) on a line by itself. (Expression statements yielding `None` are not written, so that procedure calls do not cause any output.)

## 6.2 Assignment statements

Assignment statements are used to (re)bind names to values and to modify attributes or items of mutable objects:

```
assignment_stmt ::= (target_list "=") + (expression_list | yield_expression)
target_list     ::= target ("," target) * [","]
target         ::= identifier
                | "(" target_list ")"
                | "[" target_list "]"
                | attributeref
                | subscription
                | slicing
```

(See section *Primaries* for the syntax definitions for the last three symbols.)

An assignment statement evaluates the expression list (remember that this can be a single expression or a comma-separated list, the latter yielding a tuple) and assigns the single resulting object to each of the target lists, from left to right.

Assignment is defined recursively depending on the form of the target (list). When a target is part of a mutable object (an attribute reference, subscription or slicing), the mutable object must ultimately perform the assignment and decide about its validity, and may raise an exception if the assignment is unacceptable. The rules observed by various types and the exceptions raised are given with the definition of the object types (see section *The standard type hierarchy*).

Assignment of an object to a target list is recursively defined as follows.

- If the target list is a single target: The object is assigned to that target.
- If the target list is a comma-separated list of targets: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.

Assignment of an object to a single target is recursively defined as follows.

- If the target is an identifier (name):
  - If the name does not occur in a `global` statement in the current code block: the name is bound to the object in the current local namespace.
  - Otherwise: the name is bound to the object in the current global namespace.

The name is rebound if it was already bound. This may cause the reference count for the object previously bound to the name to reach zero, causing the object to be deallocated and its destructor (if it has one) to be called.

- If the target is a target list enclosed in parentheses or in square brackets: The object must be an iterable with the same number of items as there are targets in the target list, and its items are assigned, from left to right, to the corresponding targets.
- If the target is an attribute reference: The primary expression in the reference is evaluated. It should yield an object with assignable attributes; if this is not the case, `TypeError` is raised. That object is then asked to assign the assigned object to the given attribute; if it cannot perform the assignment, it raises an exception (usually but not necessarily `AttributeError`). Note: If the object is a class instance and the attribute reference occurs on both sides of the assignment operator, the RHS expression, `a.x` can access either an instance attribute or (if no instance attribute exists) a class attribute. The LHS target `a.x` is always set as an instance attribute, creating it if necessary. Thus, the two occurrences of `a.x` do not necessarily refer to the same attribute: if the RHS expression refers to a class attribute, the LHS creates a new instance attribute as the target of the assignment:

```
class Cls:
    x = 3                # class variable
inst = Cls()
inst.x = inst.x + 1    # writes inst.x as 4 leaving Cls.x as 3
```

This description does not necessarily apply to descriptor attributes, such as properties created with `property()`.

- If the target is a subscription: The primary expression in the reference is evaluated. It should yield either a mutable sequence object (such as a list) or a mapping object (such as a dictionary). Next, the subscript expression is evaluated.

If the primary is a mutable sequence object (such as a list), the subscript must yield a plain integer. If it is negative, the sequence's length is added to it. The resulting value must be a nonnegative integer less than the sequence's length, and the sequence is asked to assign the assigned object to its item with that index. If the index is out of range, `IndexError` is raised (assignment to a subscripted sequence cannot add new items to a list).

If the primary is a mapping object (such as a dictionary), the subscript must have a type compatible with the mapping's key type, and the mapping is then asked to create a key/datum pair which maps the subscript to the assigned object. This can either replace an existing key/value pair with the same key value, or insert a new key/value pair (if no key with the same value existed).

- If the target is a slicing: The primary expression in the reference is evaluated. It should yield a mutable sequence object (such as a list). The assigned object should be a sequence object of the same type. Next, the lower and upper bound expressions are evaluated, insofar they are present; defaults are zero and the sequence's length. The bounds should evaluate to (small) integers. If either bound is negative, the sequence's length is added to it. The resulting bounds are clipped to lie between zero and the sequence's length, inclusive. Finally, the sequence object is asked to replace the slice with the items of the assigned sequence. The length of the slice may be different from the length of the assigned sequence, thus changing the length of the target sequence, if the object allows it.

**CPython implementation detail:** In the current implementation, the syntax for targets is taken to be the same as for expressions, and invalid syntax is rejected during the code generation phase, causing less detailed error messages.

**WARNING:** Although the definition of assignment implies that overlaps between the left-hand side and the right-hand side are 'safe' (for example `a, b = b, a` swaps two variables), overlaps *within* the collection of assigned-to variables are not safe! For instance, the following program prints `[0, 2]`:

```
x = [0, 1]
i = 0
i, x[i] = 1, 2
print x
```

## 6.2.1 Augmented assignment statements

Augmented assignment is the combination, in a single statement, of a binary operation and an assignment statement:

```
augmented_assignment_stmt ::= augtarget augop (expression_list | yield_expression)
augtarget                 ::= identifier | attributeref | subscription | slicing
augop                     ::= "+=" | "-=" | "*=" | "/=" | "//=" | "%=" | "**="
                           | ">>=" | "<<=" | "&=" | "^=" | "|="
```

(See section *Primitives* for the syntax definitions for the last three symbols.)

An augmented assignment evaluates the target (which, unlike normal assignment statements, cannot be an unpacking) and the expression list, performs the binary operation specific to the type of assignment on the two operands, and assigns the result to the original target. The target is only evaluated once.

An augmented assignment expression like `x += 1` can be rewritten as `x = x + 1` to achieve a similar, but not exactly equal effect. In the augmented version, `x` is only evaluated once. Also, when possible, the actual operation is performed *in-place*, meaning that rather than creating a new object and assigning that to the target, the old object is modified instead.

With the exception of assigning to tuples and multiple targets in a single statement, the assignment done by augmented assignment statements is handled the same way as normal assignments. Similarly, with the exception of the possible *in-place* behavior, the binary operation performed by augmented assignment is the same as the normal binary operations.

For targets which are attribute references, the same *caveat about class and instance attributes* applies as for regular assignments.

## 6.3 The `assert` statement

Assert statements are a convenient way to insert debugging assertions into a program:

```
assert_stmt ::= "assert" expression ["," expression]
```

The simple form, `assert expression`, is equivalent to

```
if __debug__:
    if not expression: raise AssertionError
```

The extended form, `assert expression1, expression2`, is equivalent to

```
if __debug__:
    if not expression1: raise AssertionError(expression2)
```

These equivalences assume that `__debug__` and `AssertionError` refer to the built-in variables with those names. In the current implementation, the built-in variable `__debug__` is `True` under normal circumstances, `False` when optimization is requested (command line option `-O`). The current code generator emits no code for an `assert` statement when optimization is requested at compile time. Note that it is unnecessary to include the source code for the expression that failed in the error message; it will be displayed as part of the stack trace.

Assignments to `__debug__` are illegal. The value for the built-in variable is determined when the interpreter starts.

## 6.4 The `pass` statement

```
pass_stmt ::= "pass"
```

`pass` is a null operation — when it is executed, nothing happens. It is useful as a placeholder when a statement is required syntactically, but no code needs to be executed, for example:

```
def f(arg): pass      # a function that does nothing (yet)

class C: pass        # a class with no methods (yet)
```

## 6.5 The `del` statement

```
del_stmt ::= "del" target_list
```

Deletion is recursively defined very similar to the way assignment is defined. Rather than spelling it out in full details, here are some hints.

Deletion of a target list recursively deletes each target, from left to right.

Deletion of a name removes the binding of that name from the local or global namespace, depending on whether the name occurs in a `global` statement in the same code block. If the name is unbound, a `NameError` exception will be raised.

It is illegal to delete a name from the local namespace if it occurs as a free variable in a nested block.

Deletion of attribute references, subscriptions and slicings is passed to the primary object involved; deletion of a slicing is in general equivalent to assignment of an empty slice of the right type (but even this is determined by the sliced object).

## 6.6 The `print` statement

```
print_stmt ::= "print" ([expression ("," expression)* [","]]
                | ">>" expression [("," expression)+ [","]])
```

`print` evaluates each expression in turn and writes the resulting object to standard output (see below). If an object is not a string, it is first converted to a string using the rules for string conversions. The (resulting or original) string is then written. A space is written before each object is (converted and) written, unless the output system believes it is positioned at the beginning of a line. This is the case (1) when no characters have yet been written to standard output, (2) when the last character written to standard output is a whitespace character except ' ', or (3) when the last write operation on standard output was not a `print` statement. (In some cases it may be functional to write an empty string to standard output for this reason.)

---

**Note:** Objects which act like file objects but which are not the built-in file objects often do not properly emulate this aspect of the file object's behavior, so it is best not to rely on this.

---

A ' \n ' character is written at the end, unless the `print` statement ends with a comma. This is the only action if the statement contains just the keyword `print`.

Standard output is defined as the file object named `stdout` in the built-in module `sys`. If no such object exists, or if it does not have a `write()` method, a `RuntimeError` exception is raised.

`print` also has an extended form, defined by the second portion of the syntax described above. This form is sometimes referred to as “`print` chevron.” In this form, the first expression after the `>>` must evaluate to a “file-like” object, specifically an object that has a `write()` method as described above. With this extended form, the subsequent expressions are printed to this file object. If the first expression evaluates to `None`, then `sys.stdout` is used as the file for output.

## 6.7 The `return` statement

```
return_stmt ::= "return" [expression_list]
```

`return` may only occur syntactically nested in a function definition, not within a nested class definition.

If an expression list is present, it is evaluated, else `None` is substituted.

`return` leaves the current function call with the expression list (or `None`) as return value.

When `return` passes control out of a `try` statement with a `finally` clause, that `finally` clause is executed before really leaving the function.

In a generator function, the `return` statement is not allowed to include an `expression_list`. In that context, a bare `return` indicates that the generator is done and will cause `StopIteration` to be raised.

## 6.8 The `yield` statement

```
yield_stmt ::= yield_expression
```

The `yield` statement is only used when defining a generator function, and is only used in the body of the generator function. Using a `yield` statement in a function definition is sufficient to cause that definition to create a generator function instead of a normal function.

When a generator function is called, it returns an iterator known as a generator iterator, or more commonly, a generator. The body of the generator function is executed by calling the generator's `next()` method repeatedly until it raises an exception.

When a `yield` statement is executed, the state of the generator is frozen and the value of `expression_list` is returned to `next()`'s caller. By “frozen” we mean that all local state is retained, including the current bindings of local variables, the instruction pointer, and the internal evaluation stack: enough information is saved so that the next time `next()` is invoked, the function can proceed exactly as if the `yield` statement were just another external call.

As of Python version 2.5, the `yield` statement is now allowed in the `try` clause of a `try ... finally` construct. If the generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), the generator-iterator's `close()` method will be called, allowing any pending `finally` clauses to execute.

---

**Note:** In Python 2.2, the `yield` statement was only allowed when the `generators` feature has been enabled. This `__future__` import statement was used to enable the feature:

```
from __future__ import generators
```

---

### See Also:

**PEP 0255 - Simple Generators** The proposal for adding generators and the `yield` statement to Python.

**PEP 0342 - Coroutines via Enhanced Generators** The proposal that, among other generator enhancements, proposed allowing `yield` to appear inside a `try ... finally` block.

## 6.9 The `raise` statement

```
raise_stmt ::= "raise" [expression ["," expression ["," expression]]]
```

If no expressions are present, `raise` re-raises the last exception that was active in the current scope. If no exception is active in the current scope, a `TypeError` exception is raised indicating that this is an error (if running under IDLE, a `Queue.Empty` exception is raised instead).

Otherwise, `raise` evaluates the expressions to get three objects, using `None` as the value of omitted expressions. The first two objects are used to determine the *type* and *value* of the exception.

If the first object is an instance, the type of the exception is the class of the instance, the instance itself is the value, and the second object must be `None`.

If the first object is a class, it becomes the type of the exception. The second object is used to determine the exception value: If it is an instance of the class, the instance becomes the exception value. If the second object is a tuple, it is used as the argument list for the class constructor; if it is `None`, an empty argument list is used, and any other object is treated as a single argument to the constructor. The instance so created by calling the constructor is used as the exception value.

If a third object is present and not `None`, it must be a traceback object (see section *The standard type hierarchy*), and it is substituted instead of the current location as the place where the exception occurred. If the third object is present

and not a traceback object or `None`, a `TypeError` exception is raised. The three-expression form of `raise` is useful to re-raise an exception transparently in an `except` clause, but `raise` with no expressions should be preferred if the exception to be re-raised was the most recently active exception in the current scope.

Additional information on exceptions can be found in section *Exceptions*, and information about handling exceptions is in section *The try statement*.

## 6.10 The `break` statement

```
break_stmt ::= "break"
```

`break` may only occur syntactically nested in a `for` or `while` loop, but not nested in a function or class definition within that loop.

It terminates the nearest enclosing loop, skipping the optional `else` clause if the loop has one.

If a `for` loop is terminated by `break`, the loop control target keeps its current value.

When `break` passes control out of a `try` statement with a `finally` clause, that `finally` clause is executed before really leaving the loop.

## 6.11 The `continue` statement

```
continue_stmt ::= "continue"
```

`continue` may only occur syntactically nested in a `for` or `while` loop, but not nested in a function or class definition or `finally` clause within that loop. It continues with the next cycle of the nearest enclosing loop.

When `continue` passes control out of a `try` statement with a `finally` clause, that `finally` clause is executed before really starting the next loop cycle.

## 6.12 The `import` statement

```
import_stmt ::= "import" module ["as" name] ( "," module ["as" name] )*
              | "from" relative_module "import" identifier ["as" name]
              ( "," identifier ["as" name] )*
              | "from" relative_module "import" "(" identifier ["as" name]
              ( "," identifier ["as" name] )* ["," "]" ")"
              | "from" module "import" "*"
module       ::= (identifier ".")* identifier
relative_module ::= "."* module | "."+
name        ::= identifier
```

Import statements are executed in two steps: (1) find a module, and initialize it if necessary; (2) define a name or names in the local namespace (of the scope where the `import` statement occurs). The statement comes in two forms differing on whether it uses the `from` keyword. The first form (without `from`) repeats these steps for each identifier in the list. The form with `from` performs step (1) once, and then performs step (2) repeatedly.

To understand how step (1) occurs, one must first understand how Python handles hierarchical naming of modules. To help organize modules and provide a hierarchy in naming, Python has a concept of packages. A package can

contain other packages and modules while modules cannot contain other modules or packages. From a file system perspective, packages are directories and modules are files. The original [specification for packages](#) is still available to read, although minor details have changed since the writing of that document.

Once the name of the module is known (unless otherwise specified, the term “module” will refer to both packages and modules), searching for the module or package can begin. The first place checked is `sys.modules`, the cache of all modules that have been imported previously. If the module is found there then it is used in step (2) of import.

If the module is not found in the cache, then `sys.meta_path` is searched (the specification for `sys.meta_path` can be found in [PEP 302](#)). The object is a list of *finder* objects which are queried in order as to whether they know how to load the module by calling their `find_module()` method with the name of the module. If the module happens to be contained within a package (as denoted by the existence of a dot in the name), then a second argument to `find_module()` is given as the value of the `__path__` attribute from the parent package (everything up to the last dot in the name of the module being imported). If a finder can find the module it returns a *loader* (discussed later) or returns `None`.

If none of the finders on `sys.meta_path` are able to find the module then some implicitly defined finders are queried. Implementations of Python vary in what implicit meta path finders are defined. The one they all do define, though, is one that handles `sys.path_hooks`, `sys.path_importer_cache`, and `sys.path`.

The implicit finder searches for the requested module in the “paths” specified in one of two places (“paths” do not have to be file system paths). If the module being imported is supposed to be contained within a package then the second argument passed to `find_module()`, `__path__` on the parent package, is used as the source of paths. If the module is not contained in a package then `sys.path` is used as the source of paths.

Once the source of paths is chosen it is iterated over to find a finder that can handle that path. The dict at `sys.path_importer_cache` caches finders for paths and is checked for a finder. If the path does not have a finder cached then `sys.path_hooks` is searched by calling each object in the list with a single argument of the path, returning a finder or raises `ImportError`. If a finder is returned then it is cached in `sys.path_importer_cache` and then used for that path entry. If no finder can be found but the path exists then a value of `None` is stored in `sys.path_importer_cache` to signify that an implicit, file-based finder that handles modules stored as individual files should be used for that path. If the path does not exist then a finder which always returns `None` is placed in the cache for the path.

If no finder can find the module then `ImportError` is raised. Otherwise some finder returned a loader whose `load_module()` method is called with the name of the module to load (see [PEP 302](#) for the original definition of loaders). A loader has several responsibilities to perform on a module it loads. First, if the module already exists in `sys.modules` (a possibility if the loader is called outside of the import machinery) then it is to use that module for initialization and not a new module. But if the module does not exist in `sys.modules` then it is to be added to that dict before initialization begins. If an error occurs during loading of the module and it was added to `sys.modules` it is to be removed from the dict. If an error occurs but the module was already in `sys.modules` it is left in the dict.

The loader must set several attributes on the module. `__name__` is to be set to the name of the module. `__file__` is to be the “path” to the file unless the module is built-in (and thus listed in `sys.builtin_module_names`) in which case the attribute is not set. If what is being imported is a package then `__path__` is to be set to a list of paths to be searched when looking for modules and packages contained within the package being imported. `__package__` is optional but should be set to the name of package that contains the module or package (the empty string is used for module not contained in a package). `__loader__` is also optional but should be set to the loader object that is loading the module.

If an error occurs during loading then the loader raises `ImportError` if some other exception is not already being propagated. Otherwise the loader returns the module that was loaded and initialized.

When step (1) finishes without raising an exception, step (2) can begin.

The first form of `import` statement binds the module name in the local namespace to the module object, and then goes on to import the next identifier, if any. If the module name is followed by `as`, the name following `as` is used as the local name for the module.

The `from` form does not bind the module name: it goes through the list of identifiers, looks each one of them up in the module found in step (1), and binds the name in the local namespace to the object thus found. As with the first form of `import`, an alternate local name can be supplied by specifying “`as localname`”. If a name is not found, `ImportError` is raised. If the list of identifiers is replaced by a star (`' * '`), all public names defined in the module are bound in the local namespace of the `import` statement..

The *public names* defined by a module are determined by checking the module’s namespace for a variable named `__all__`; if defined, it must be a sequence of strings which are names defined or imported by that module. The names given in `__all__` are all considered public and are required to exist. If `__all__` is not defined, the set of public names includes all names found in the module’s namespace which do not begin with an underscore character (`' _ '`). `__all__` should contain the entire public API. It is intended to avoid accidentally exporting items that are not part of the API (such as library modules which were imported and used within the module).

The `from` form with `*` may only occur in a module scope. If the wild card form of import — `import *` — is used in a function and the function contains or is a nested block with free variables, the compiler will raise a `SyntaxError`.

When specifying what module to import you do not have to specify the absolute name of the module. When a module or package is contained within another package it is possible to make a relative import within the same top package without having to mention the package name. By using leading dots in the specified module or package after `from` you can specify how high to traverse up the current package hierarchy without specifying exact names. One leading dot means the current package where the module making the import exists. Two dots means up one package level. Three dots is up two levels, etc. So if you execute `from . import mod` from a module in the `pkg` package then you will end up importing `pkg.mod`. If you execute `from ..subpkg2 import mod` from within `pkg.subpkg1` you will import `pkg.subpkg2.mod`. The specification for relative imports is contained within [PEP 328](#).

`importlib.import_module()` is provided to support applications that determine which modules need to be loaded dynamically.

### 6.12.1 Future statements

A *future statement* is a directive to the compiler that a particular module should be compiled using syntax or semantics that will be available in a specified future release of Python. The future statement is intended to ease migration to future versions of Python that introduce incompatible changes to the language. It allows use of the new features on a per-module basis before the release in which the feature becomes standard.

```
future_statement ::= "from" "__future__" "import" feature ["as" name]
                  ("," feature ["as" name])*
                  | "from" "__future__" "import" "(" feature ["as" name]
                  ("," feature ["as" name])* [","] ")"
feature           ::= identifier
name             ::= identifier
```

A future statement must appear near the top of the module. The only lines that can appear before a future statement are:

- the module docstring (if any),
- comments,
- blank lines, and
- other future statements.

The features recognized by Python 2.6 are `unicode_literals`, `print_function`, `absolute_import`, `division`, `generators`, `nested_scopes` and `with_statement`. `generators`, `with_statement`, `nested_scopes` are redundant in Python version 2.6 and above because they are always enabled.

A future statement is recognized and treated specially at compile time: Changes to the semantics of core constructs are often implemented by generating different code. It may even be the case that a new feature introduces new incompatible syntax (such as a new reserved word), in which case the compiler may need to parse the module differently. Such decisions cannot be pushed off until runtime.

For any given release, the compiler knows which feature names have been defined, and raises a compile-time error if a future statement contains a feature not known to it.

The direct runtime semantics are the same as for any import statement: there is a standard module `__future__`, described later, and it will be imported in the usual way at the time the future statement is executed.

The interesting runtime semantics depend on the specific feature enabled by the future statement.

Note that there is nothing special about the statement:

```
import __future__ [as name]
```

That is not a future statement; it's an ordinary import statement with no special semantics or syntax restrictions.

Code compiled by an `exec` statement or calls to the built-in functions `compile()` and `execfile()` that occur in a module `M` containing a future statement will, by default, use the new syntax or semantics associated with the future statement. This can, starting with Python 2.2 be controlled by optional arguments to `compile()` — see the documentation of that function for details.

A future statement typed at an interactive interpreter prompt will take effect for the rest of the interpreter session. If an interpreter is started with the `-i` option, is passed a script name to execute, and the script includes a future statement, it will be in effect in the interactive session started after the script is executed.

### See Also:

**PEP 236 - Back to the `__future__`** The original proposal for the `__future__` mechanism.

## 6.13 The `global` statement

```
global_stmt ::= "global" identifier ("," identifier)*
```

The `global` statement is a declaration which holds for the entire current code block. It means that the listed identifiers are to be interpreted as globals. It would be impossible to assign to a global variable without `global`, although free variables may refer to globals without being declared `global`.

Names listed in a `global` statement must not be used in the same code block textually preceding that `global` statement.

Names listed in a `global` statement must not be defined as formal parameters or in a `for` loop control target, `class` definition, function definition, or `import` statement.

**CPython implementation detail:** The current implementation does not enforce the latter two restrictions, but programs should not abuse this freedom, as future implementations may enforce them or silently change the meaning of the program.

**Programmer's note:** the `global` is a directive to the parser. It applies only to code parsed at the same time as the `global` statement. In particular, a `global` statement contained in an `exec` statement does not affect the code block containing the `exec` statement, and code contained in an `exec` statement is unaffected by `global` statements in the code containing the `exec` statement. The same applies to the `eval()`, `execfile()` and `compile()` functions.

## 6.14 The `exec` statement

```
exec_stmt ::= "exec" or_expr ["in" expression ["," expression]]
```

This statement supports dynamic execution of Python code. The first expression should evaluate to either a string, an open file object, or a code object. If it is a string, the string is parsed as a suite of Python statements which is then executed (unless a syntax error occurs).<sup>1</sup> If it is an open file, the file is parsed until EOF and executed. If it is a code object, it is simply executed. In all cases, the code that's executed is expected to be valid as file input (see section *File input*). Be aware that the `return` and `yield` statements may not be used outside of function definitions even within the context of code passed to the `exec` statement.

In all cases, if the optional parts are omitted, the code is executed in the current scope. If only the first expression after `in` is specified, it should be a dictionary, which will be used for both the global and the local variables. If two expressions are given, they are used for the global and local variables, respectively. If provided, *locals* can be any mapping object. Remember that at module level, *globals* and *locals* are the same dictionary. If two separate objects are given as *globals* and *locals*, the code will be executed as if it were embedded in a class definition. Changed in version 2.4: Formerly, *locals* was required to be a dictionary. As a side effect, an implementation may insert additional keys into the dictionaries given besides those corresponding to variable names set by the executed code. For example, the current implementation may add a reference to the dictionary of the built-in module `__builtin__` under the key `__builtins__` (!).

**Programmer's hints:** dynamic evaluation of expressions is supported by the built-in function `eval()`. The built-in functions `globals()` and `locals()` return the current global and local dictionary, respectively, which may be useful to pass around for use by `exec`.

---

<sup>1</sup> Note that the parser only accepts the Unix-style end of line convention. If you are reading the code from a file, make sure to use *universal newlines* mode to convert Windows or Mac-style newlines.



# COMPOUND STATEMENTS

Compound statements contain (groups of) other statements; they affect or control the execution of those other statements in some way. In general, compound statements span multiple lines, although in simple incarnations a whole compound statement may be contained in one line.

The `if`, `while` and `for` statements implement traditional control flow constructs. `try` specifies exception handlers and/or cleanup code for a group of statements. Function and class definitions are also syntactically compound statements.

Compound statements consist of one or more ‘clauses.’ A clause consists of a header and a ‘suite.’ The clause headers of a particular compound statement are all at the same indentation level. Each clause header begins with a uniquely identifying keyword and ends with a colon. A suite is a group of statements controlled by a clause. A suite can be one or more semicolon-separated simple statements on the same line as the header, following the header’s colon, or it can be one or more indented statements on subsequent lines. Only the latter form of suite can contain nested compound statements; the following is illegal, mostly because it wouldn’t be clear to which `if` clause a following `else` clause would belong:

```
if test1: if test2: print x
```

Also note that the semicolon binds tighter than the colon in this context, so that in the following example, either all or none of the `print` statements are executed:

```
if x < y < z: print x; print y; print z
```

Summarizing:

```
compound_stmt ::= if_stmt
                | while_stmt
                | for_stmt
                | try_stmt
                | with_stmt
                | funcdef
                | classdef
                | decorated

suite          ::= stmt_list NEWLINE | NEWLINE INDENT statement+ DEDENT
statement     ::= stmt_list NEWLINE | compound_stmt
stmt_list     ::= simple_stmt (";" simple_stmt)* [";"]
```

Note that statements always end in a `NEWLINE` possibly followed by a `DEDENT`. Also note that optional continuation clauses always begin with a keyword that cannot start a statement, thus there are no ambiguities (the ‘dangling `else`’ problem is solved in Python by requiring nested `if` statements to be indented).

The formatting of the grammar rules in the following sections places each clause on a separate line for clarity.

## 7.1 The `if` statement

The `if` statement is used for conditional execution:

```
if_stmt ::= "if" expression ":" suite
         ( "elif" expression ":" suite )*
         ["else" ":" suite]
```

It selects exactly one of the suites by evaluating the expressions one by one until one is found to be true (see section *Boolean operations* for the definition of true and false); then that suite is executed (and no other part of the `if` statement is executed or evaluated). If all expressions are false, the suite of the `else` clause, if present, is executed.

## 7.2 The `while` statement

The `while` statement is used for repeated execution as long as an expression is true:

```
while_stmt ::= "while" expression ":" suite
            ["else" ":" suite]
```

This repeatedly tests the expression and, if it is true, executes the first suite; if the expression is false (which may be the first time it is tested) the suite of the `else` clause, if present, is executed and the loop terminates.

A `break` statement executed in the first suite terminates the loop without executing the `else` clause's suite. A `continue` statement executed in the first suite skips the rest of the suite and goes back to testing the expression.

## 7.3 The `for` statement

The `for` statement is used to iterate over the elements of a sequence (such as a string, tuple or list) or other iterable object:

```
for_stmt ::= "for" target_list "in" expression_list ":" suite
           ["else" ":" suite]
```

The expression list is evaluated once; it should yield an iterable object. An iterator is created for the result of the `expression_list`. The suite is then executed once for each item provided by the iterator, in the order of ascending indices. Each item in turn is assigned to the target list using the standard rules for assignments, and then the suite is executed. When the items are exhausted (which is immediately when the sequence is empty), the suite in the `else` clause, if present, is executed, and the loop terminates.

A `break` statement executed in the first suite terminates the loop without executing the `else` clause's suite. A `continue` statement executed in the first suite skips the rest of the suite and continues with the next item, or with the `else` clause if there was no next item.

The suite may assign to the variable(s) in the target list; this does not affect the next item assigned to it.

The target list is not deleted when the loop is finished, but if the sequence is empty, it will not have been assigned to at all by the loop. Hint: the built-in function `range()` returns a sequence of integers suitable to emulate the effect of Pascal's `for i := a to b do`; e.g., `range(3)` returns the list `[0, 1, 2]`.

---

**Note:** There is a subtlety when the sequence is being modified by the loop (this can only occur for mutable sequences, i.e. lists). An internal counter is used to keep track of which item is used next, and this is incremented on each iteration. When this counter has reached the length of the sequence the loop terminates. This means that if the suite deletes the

current (or a previous) item from the sequence, the next item will be skipped (since it gets the index of the current item which has already been treated). Likewise, if the suite inserts an item in the sequence before the current item, the current item will be treated again the next time through the loop. This can lead to nasty bugs that can be avoided by making a temporary copy using a slice of the whole sequence, e.g.,

```
for x in a[:]:
    if x < 0: a.remove(x)
```

## 7.4 The `try` statement

The `try` statement specifies exception handlers and/or cleanup code for a group of statements:

```
try_stmt ::= try1_stmt | try2_stmt
try1_stmt ::= "try" ":" suite
              ("except" [expression [("as" | ",") target]] ":" suite)+
              ["else" ":" suite]
              ["finally" ":" suite]
try2_stmt ::= "try" ":" suite
              "finally" ":" suite
```

Changed in version 2.5: In previous versions of Python, `try...except...finally` did not work. `try...except` had to be nested in `try...finally`. The `except` clause(s) specify one or more exception handlers. When no exception occurs in the `try` clause, no exception handler is executed. When an exception occurs in the `try` suite, a search for an exception handler is started. This search inspects the `except` clauses in turn until one is found that matches the exception. An expression-less `except` clause, if present, must be last; it matches any exception. For an `except` clause with an expression, that expression is evaluated, and the clause matches the exception if the resulting object is “compatible” with the exception. An object is compatible with an exception if it is the class or a base class of the exception object, a tuple containing an item compatible with the exception, or, in the (deprecated) case of string exceptions, is the raised string itself (note that the object identities must match, i.e. it must be the same string object, not just a string with the same value).

If no `except` clause matches the exception, the search for an exception handler continues in the surrounding code and on the invocation stack.<sup>1</sup>

If the evaluation of an expression in the header of an `except` clause raises an exception, the original search for a handler is canceled and a search starts for the new exception in the surrounding code and on the call stack (it is treated as if the entire `try` statement raised the exception).

When a matching `except` clause is found, the exception is assigned to the target specified in that `except` clause, if present, and the `except` clause’s suite is executed. All `except` clauses must have an executable block. When the end of this block is reached, execution continues normally after the entire `try` statement. (This means that if two nested handlers exist for the same exception, and the exception occurs in the `try` clause of the inner handler, the outer handler will not handle the exception.)

Before an `except` clause’s suite is executed, details about the exception are assigned to three variables in the `sys` module: `sys.exc_type` receives the object identifying the exception; `sys.exc_value` receives the exception’s parameter; `sys.exc_traceback` receives a traceback object (see section *The standard type hierarchy*) identifying the point in the program where the exception occurred. These details are also available through the `sys.exc_info()` function, which returns a tuple (`exc_type`, `exc_value`, `exc_traceback`). Use of the corresponding variables is deprecated in favor of this function, since their use is unsafe in a threaded program. As of Python 1.5, the

<sup>1</sup> The exception is propagated to the invocation stack unless there is a `finally` clause which happens to raise another exception. That new exception causes the old one to be lost.

variables are restored to their previous values (before the call) when returning from a function that handled an exception.

The optional `else` clause is executed if and when control flows off the end of the `try` clause.<sup>2</sup> Exceptions in the `else` clause are not handled by the preceding `except` clauses.

If `finally` is present, it specifies a ‘cleanup’ handler. The `try` clause is executed, including any `except` and `else` clauses. If an exception occurs in any of the clauses and is not handled, the exception is temporarily saved. The `finally` clause is executed. If there is a saved exception or `break` statement, it is re-raised at the end of the `finally` clause. If the `finally` clause raises another exception the saved exception is set as the context of the new exception; if the `finally` clause executes a `return` statement, the saved exception is discarded:

```
def f():
    try:
        1/0
    finally:
        return 42
```

```
>>> f()
42
```

The exception information is not available to the program during execution of the `finally` clause.

When a `return`, `break` or `continue` statement is executed in the `try` suite of a `try...finally` statement, the `finally` clause is also executed ‘on the way out.’ A `continue` statement is illegal in the `finally` clause. (The reason is a problem with the current implementation — this restriction may be lifted in the future).

Additional information on exceptions can be found in section *Exceptions*, and information on using the `raise` statement to generate exceptions may be found in section *The raise statement*.

## 7.5 The `with` statement

New in version 2.5. The `with` statement is used to wrap the execution of a block with methods defined by a context manager (see section *With Statement Context Managers*). This allows common `try...except...finally` usage patterns to be encapsulated for convenient reuse.

```
with_stmt ::= "with" with_item ("," with_item)* ":" suite
with_item ::= expression ["as" target]
```

The execution of the `with` statement with one “item” proceeds as follows:

1. The context expression (the expression given in the `with_item`) is evaluated to obtain a context manager.
2. The context manager’s `__exit__()` is loaded for later use.
3. The context manager’s `__enter__()` method is invoked.
4. If a target was included in the `with` statement, the return value from `__enter__()` is assigned to it.

---

**Note:** The `with` statement guarantees that if the `__enter__()` method returns without an error, then `__exit__()` will always be called. Thus, if an error occurs during the assignment to the target list, it will be treated the same as an error occurring within the suite would be. See step 6 below.

---

5. The suite is executed.

---

<sup>2</sup> Currently, control “flows off the end” except in the case of an exception or the execution of a `return`, `continue`, or `break` statement.

6. The context manager's `__exit__()` method is invoked. If an exception caused the suite to be exited, its type, value, and traceback are passed as arguments to `__exit__()`. Otherwise, three `None` arguments are supplied.

If the suite was exited due to an exception, and the return value from the `__exit__()` method was false, the exception is reraised. If the return value was true, the exception is suppressed, and execution continues with the statement following the `with` statement.

If the suite was exited for any reason other than an exception, the return value from `__exit__()` is ignored, and execution proceeds at the normal location for the kind of exit that was taken.

With more than one item, the context managers are processed as if multiple `with` statements were nested:

```
with A() as a, B() as b:
    suite
```

is equivalent to

```
with A() as a:
    with B() as b:
        suite
```

---

**Note:** In Python 2.5, the `with` statement is only allowed when the `with_statement` feature has been enabled. It is always enabled in Python 2.6.

---

Changed in version 2.7: Support for multiple context expressions.

**See Also:**

**PEP 0343 - The “with” statement** The specification, background, and examples for the Python `with` statement.

## 7.6 Function definitions

A function definition defines a user-defined function object (see section *The standard type hierarchy*):

```
decorated      ::= decorators (classdef | funcdef)
decorators     ::= decorator+
decorator      ::= "@" dotted_name ["(" [argument_list [","]] ")"] NEWLINE
funcdef        ::= "def" funcname "(" [parameter_list "]" ":" suite
dotted_name    ::= identifier ( "." identifier ) *
parameter_list ::= (defparameter ",") *
                ( "*" identifier [, "*" identifier
                | "*" identifier
                | defparameter [","] )
defparameter   ::= parameter ["=" expression]
sublist        ::= parameter ( "," parameter ) * [ "," ]
parameter      ::= identifier | "(" sublist ")"
funcname       ::= identifier
```

A function definition is an executable statement. Its execution binds the function name in the current local namespace to a function object (a wrapper around the executable code for the function). This function object contains a reference to the current global namespace as the global namespace to be used when the function is called.

The function definition does not execute the function body; this gets executed only when the function is called.<sup>3</sup>

---

<sup>3</sup> A string literal appearing as the first statement in the function body is transformed into the function's `__doc__` attribute and therefore the function's *docstring*.

A function definition may be wrapped by one or more *decorator* expressions. Decorator expressions are evaluated when the function is defined, in the scope that contains the function definition. The result must be a callable, which is invoked with the function object as the only argument. The returned value is bound to the function name instead of the function object. Multiple decorators are applied in nested fashion. For example, the following code:

```
@f1(arg)
@f2
def func(): pass
```

is equivalent to:

```
def func(): pass
func = f1(arg)(f2(func))
```

When one or more top-level parameters have the form *parameter = expression*, the function is said to have “default parameter values.” For a parameter with a default value, the corresponding argument may be omitted from a call, in which case the parameter’s default value is substituted. If a parameter has a default value, all following parameters must also have a default value — this is a syntactic restriction that is not expressed by the grammar.

**Default parameter values are evaluated when the function definition is executed.** This means that the expression is evaluated once, when the function is defined, and that the same “pre-computed” value is used for each call. This is especially important to understand when a default parameter is a mutable object, such as a list or a dictionary: if the function modifies the object (e.g. by appending an item to a list), the default value is in effect modified. This is generally not what was intended. A way around this is to use `None` as the default, and explicitly test for it in the body of the function, e.g.:

```
def whats_on_the_telly(penguin=None):
    if penguin is None:
        penguin = []
    penguin.append("property of the zoo")
    return penguin
```

Function call semantics are described in more detail in section *Calls*. A function call always assigns values to all parameters mentioned in the parameter list, either from position arguments, from keyword arguments, or from default values. If the form “*\*identifier*” is present, it is initialized to a tuple receiving any excess positional parameters, defaulting to the empty tuple. If the form “*\*\*identifier*” is present, it is initialized to a new dictionary receiving any excess keyword arguments, defaulting to a new empty dictionary.

It is also possible to create anonymous functions (functions not bound to a name), for immediate use in expressions. This uses lambda forms, described in section *Lambdas*. Note that the lambda form is merely a shorthand for a simplified function definition; a function defined in a “def” statement can be passed around or assigned to another name just like a function defined by a lambda form. The “def” form is actually more powerful since it allows the execution of multiple statements.

**Programmer’s note:** Functions are first-class objects. A “def” form executed inside a function definition defines a local function that can be returned or passed around. Free variables used in the nested function can access the local variables of the function containing the def. See section *Naming and binding* for details.

## 7.7 Class definitions

A class definition defines a class object (see section *The standard type hierarchy*):

```
classdef ::= "class" classname [inheritance] ":" suite
inheritance ::= "(" [expression_list] ")"
classname ::= identifier
```

A class definition is an executable statement. It first evaluates the inheritance list, if present. Each item in the inheritance list should evaluate to a class object or class type which allows subclassing. The class's suite is then executed in a new execution frame (see section *Naming and binding*), using a newly created local namespace and the original global namespace. (Usually, the suite contains only function definitions.) When the class's suite finishes execution, its execution frame is discarded but its local namespace is saved.<sup>4</sup> A class object is then created using the inheritance list for the base classes and the saved local namespace for the attribute dictionary. The class name is bound to this class object in the original local namespace.

**Programmer's note:** Variables defined in the class definition are class variables; they are shared by all instances. To create instance variables, they can be set in a method with `self.name = value`. Both class and instance variables are accessible through the notation "`self.name`", and an instance variable hides a class variable with the same name when accessed in this way. Class variables can be used as defaults for instance variables, but using mutable values there can lead to unexpected results. For *new-style classes*, descriptors can be used to create instance variables with different implementation details.

Class definitions, like function definitions, may be wrapped by one or more *decorator* expressions. The evaluation rules for the decorator expressions are the same as for functions. The result must be a class object, which is then bound to the class name.

---

<sup>4</sup> A string literal appearing as the first statement in the class body is transformed into the namespace's `__doc__` item and therefore the class's *docstring*.



# TOP-LEVEL COMPONENTS

The Python interpreter can get its input from a number of sources: from a script passed to it as standard input or as program argument, typed in interactively, from a module source file, etc. This chapter gives the syntax used in these cases.

## 8.1 Complete Python programs

While a language specification need not prescribe how the language interpreter is invoked, it is useful to have a notion of a complete Python program. A complete Python program is executed in a minimally initialized environment: all built-in and standard modules are available, but none have been initialized, except for `sys` (various system services), `__builtin__` (built-in functions, exceptions and `None`) and `__main__`. The latter is used to provide the local and global namespace for execution of the complete program.

The syntax for a complete Python program is that for file input, described in the next section.

The interpreter may also be invoked in interactive mode; in this case, it does not read and execute a complete program but reads and executes one statement (possibly compound) at a time. The initial environment is identical to that of a complete program; each statement is executed in the namespace of `__main__`.

Under Unix, a complete program can be passed to the interpreter in three forms: with the `-c string` command line option, as a file passed as the first command line argument, or as standard input. If the file or standard input is a tty device, the interpreter enters interactive mode; otherwise, it executes the file as a complete program.

## 8.2 File input

All input read from non-interactive files has the same form:

```
file_input ::= (NEWLINE | statement)*
```

This syntax is used in the following situations:

- when parsing a complete Python program (from a file or from a string);
- when parsing a module;
- when parsing a string passed to the `exec` statement;

## 8.3 Interactive input

Input in interactive mode is parsed using the following grammar:

```
interactive_input ::= [stmt_list] NEWLINE | compound_stmt NEWLINE
```

Note that a (top-level) compound statement must be followed by a blank line in interactive mode; this is needed to help the parser detect the end of the input.

## 8.4 Expression input

There are two forms of expression input. Both ignore leading whitespace. The string argument to `eval()` must have the following form:

```
eval_input ::= expression_list NEWLINE*
```

The input line read by `input()` must have the following form:

```
input_input ::= expression_list NEWLINE
```

Note: to read ‘raw’ input line without interpretation, you can use the built-in function `raw_input()` or the `readline()` method of file objects.

# FULL GRAMMAR SPECIFICATION

This is the full Python grammar, as it is read by the parser generator and used to parse Python source files:

```
# Grammar for Python

# Note: Changing the grammar specified in this file will most likely
# require corresponding changes in the parser module
# (./Modules/parsermodule.c). If you can't make the changes to
# that module yourself, please co-ordinate the required changes
# with someone who can; ask around on python-dev for help. Fred
# Drake <fdrake@acm.org> will probably be listening there.

# NOTE WELL: You should also follow all the steps listed in PEP 306,
# "How to Change Python's Grammar"

# Start symbols for the grammar:
#   single_input is a single interactive statement;
#   file_input is a module or sequence of commands read from an input file;
#   eval_input is the input for the eval() and input() functions.
# NB: compound_stmt in single_input is followed by extra NEWLINE!
single_input: NEWLINE | simple_stmt | compound_stmt NEWLINE
file_input: (NEWLINE | stmt)* ENDMARKER
eval_input: testlist NEWLINE* ENDMARKER

decorator: '@' dotted_name [ '(' [arglist] ')' ] NEWLINE
decorators: decorator+
decorated: decorators (classdef | funcdef)
funcdef: 'def' NAME parameters ':' suite
parameters: '(' [vararglist] ')'
vararglist: ((fpdef ['=' test] ',')*
              ('*' NAME [', ' '**' NAME] | '**' NAME) |
              fpdef ['=' test] (',' fpdef ['=' test])* [','])
fpdef: NAME | '(' fplist ')'
fplist: fpdef (',' fpdef)* [',']

stmt: simple_stmt | compound_stmt
simple_stmt: small_stmt (';' small_stmt)* [';'] NEWLINE
small_stmt: (expr_stmt | print_stmt | del_stmt | pass_stmt | flow_stmt |
             import_stmt | global_stmt | exec_stmt | assert_stmt)
expr_stmt: testlist (augassign (yield_expr|testlist) |
                    ('=' (yield_expr|testlist))*
```

```
augassign: ('+=' | '-=' | '*=' | '/=' | '%=' | '&=' | '|=' | '^=' |
           '<<=' | '>>=' | '**=' | '//=')
# For normal assignments, additional restrictions enforced by the interpreter
print_stmt: 'print' ( [ test (',' test)* [',' ] ] |
                    '>>' test [ (',' test)+ [',' ] ] )
del_stmt: 'del' exprlist
pass_stmt: 'pass'
flow_stmt: break_stmt | continue_stmt | return_stmt | raise_stmt | yield_stmt
break_stmt: 'break'
continue_stmt: 'continue'
return_stmt: 'return' [testlist]
yield_stmt: yield_expr
raise_stmt: 'raise' [test [',' test [',' test]]]
import_stmt: import_name | import_from
import_name: 'import' dotted_as_names
import_from: ('from' ('.*' dotted_name | '.'+)
             'import' ('*' | '(' import_as_names ')') | import_as_names)
import_as_name: NAME ['as' NAME]
dotted_as_name: dotted_name ['as' NAME]
import_as_names: import_as_name (',' import_as_name)* [',' ]
dotted_as_names: dotted_as_name (',' dotted_as_name)*
dotted_name: NAME ('.' NAME)*
global_stmt: 'global' NAME (',' NAME)*
exec_stmt: 'exec' expr ['in' test [',' test]]
assert_stmt: 'assert' test [',' test]

compound_stmt: if_stmt | while_stmt | for_stmt | try_stmt | with_stmt | funcdef | classdef
if_stmt: 'if' test ':' suite ('elif' test ':' suite)* ['else' ':' suite]
while_stmt: 'while' test ':' suite ['else' ':' suite]
for_stmt: 'for' exprlist 'in' testlist ':' suite ['else' ':' suite]
try_stmt: ('try' ':' suite
          ((except_clause ':' suite)+
           ['else' ':' suite]
           ['finally' ':' suite] |
           'finally' ':' suite))
with_stmt: 'with' with_item (',' with_item)* ':' suite
with_item: test ['as' expr]
# NB compile.c makes sure that the default except clause is last
except_clause: 'except' [test [( 'as' | ',' ) test]]
suite: simple_stmt | NEWLINE INDENT stmt+ DEDENT

# Backward compatibility cruft to support:
# [ x for x in lambda: True, lambda: False if x() ]
# even while also allowing:
# lambda x: 5 if x else 2
# (But not a mix of the two)
testlist_safe: old_test [(',' old_test)+ [',' ]]
old_test: or_test | old_lambdef
old_lambdef: 'lambda' [varargslist] ':' old_test

test: or_test ['if' or_test 'else' test] | lambdef
or_test: and_test ('or' and_test)*
and_test: not_test ('and' not_test)*
not_test: 'not' not_test | comparison
```

```

comparison: expr (comp_op expr)*
comp_op: '<' | '>' | '==' | '>=' | '<=' | '<>' | '!=' | 'in' | 'not in' | 'is' | 'is not'
expr: xor_expr ('|' xor_expr)*
xor_expr: and_expr ('^' and_expr)*
and_expr: shift_expr ('&' shift_expr)*
shift_expr: arith_expr (('<<' | '>>') arith_expr)*
arith_expr: term (('+' | '-') term)*
term: factor (('*' | '/' | '%' | '//') factor)*
factor: ('+' | '-' | '~') factor | power
power: atom trailer* ['**' factor]
atom: ((' [yield_expr|testlist_comp] ') |
      '[' [listmaker] ']' |
      '{' [dictorsetmaker] '}' |
      ''' testlist1 ''' |
      NAME | NUMBER | STRING+)
listmaker: test ( list_for | (',' test)* [',' ] )
testlist_comp: test ( comp_for | (',' test)* [',' ] )
lambdef: 'lambda' [vararglist] ':' test
trailer: '(' [arglist] ')' | '[' subscriptlist ']' | '.' NAME
subscriptlist: subscript (',' subscript)* [',' ]
subscript: '.' '.' '.' | test | [test] ':' [test] [sliceop]
sliceop: ':' [test]
exprlist: expr (',' expr)* [',' ]
testlist: test (',' test)* [',' ]
dictorsetmaker: ( (test ':' test (comp_for | (',' test ':' test)* [',' ])) |
                  (test (comp_for | (',' test)* [',' ])) )

classdef: 'class' NAME [(' [testlist] ')'] ':' suite

arglist: (argument ',' )* (argument [',' ]
                          | '**' test (',' argument)* [',' '**' test]
                          | '**' test)
# The reason that keywords are test nodes instead of NAME is that using NAME
# results in an ambiguity. ast.c makes sure it's a NAME.
argument: test [comp_for] | test '=' test

list_iter: list_for | list_if
list_for: 'for' exprlist 'in' testlist_safe [list_iter]
list_if: 'if' old_test [list_iter]

comp_iter: comp_for | comp_if
comp_for: 'for' exprlist 'in' or_test [comp_iter]
comp_if: 'if' old_test [comp_iter]

testlist1: test (',' test)*

# not used in grammar, but may appear in "node" passed from Parser to Compiler
encoding_decl: NAME

yield_expr: 'yield' [testlist]

```



---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**...** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for [function definitions](#) and [class definitions](#) for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see [Implementing Descriptors](#).

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a for-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator’s `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *Customizing class creation*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See *The Python 2.3 Method Resolution Order*.

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *New-style and classic classes*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *Special method names*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

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These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

Continued on next page

Table C.1 – continued from previous page

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

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The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
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```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
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### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
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```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
           references to Ghostscript; clarified derivation from RFC 1321;
           now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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Modified by Jack Jansen, CWI, July 1995:

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- Arguments more compliant with Python standard

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# Python Frequently Asked Questions

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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# GENERAL PYTHON FAQ

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## 1.1 General Information

### 1.1.1 What is Python?

Python is an interpreted, interactive, object-oriented programming language. It incorporates modules, exceptions, dynamic typing, very high level dynamic data types, and classes. Python combines remarkable power with very clear syntax. It has interfaces to many system calls and libraries, as well as to various window systems, and is extensible in C or C++. It is also usable as an extension language for applications that need a programmable interface. Finally, Python is portable: it runs on many Unix variants, on the Mac, and on PCs under MS-DOS, Windows, Windows NT, and OS/2.

To find out more, start with *tutorial-index*. The [Beginner's Guide to Python](#) links to other introductory tutorials and resources for learning Python.

### 1.1.2 What is the Python Software Foundation?

The Python Software Foundation is an independent non-profit organization that holds the copyright on Python versions 2.1 and newer. The PSF's mission is to advance open source technology related to the Python programming language and to publicize the use of Python. The PSF's home page is at <http://www.python.org/psf/>.

Donations to the PSF are tax-exempt in the US. If you use Python and find it helpful, please contribute via the [PSF donation page](#).

### 1.1.3 Are there copyright restrictions on the use of Python?

You can do anything you want with the source, as long as you leave the copyrights in and display those copyrights in any documentation about Python that you produce. If you honor the copyright rules, it's OK to use Python for commercial use, to sell copies of Python in source or binary form (modified or unmodified), or to sell products that incorporate Python in some form. We would still like to know about all commercial use of Python, of course.

See the [PSF license page](#) to find further explanations and a link to the full text of the license.

The Python logo is trademarked, and in certain cases permission is required to use it. Consult the [Trademark Usage Policy](#) for more information.

### 1.1.4 Why was Python created in the first place?

Here's a *very* brief summary of what started it all, written by Guido van Rossum:

I had extensive experience with implementing an interpreted language in the ABC group at CWI, and from working with this group I had learned a lot about language design. This is the origin of many Python features, including the use of indentation for statement grouping and the inclusion of very-high-level data types (although the details are all different in Python).

I had a number of gripes about the ABC language, but also liked many of its features. It was impossible to extend the ABC language (or its implementation) to remedy my complaints – in fact its lack of extensibility was one of its biggest problems. I had some experience with using Modula-2+ and talked with the designers of Modula-3 and read the Modula-3 report. Modula-3 is the origin of the syntax and semantics used for exceptions, and some other Python features.

I was working in the Amoeba distributed operating system group at CWI. We needed a better way to do system administration than by writing either C programs or Bourne shell scripts, since Amoeba had its own system call interface which wasn't easily accessible from the Bourne shell. My experience with error

handling in Amoeba made me acutely aware of the importance of exceptions as a programming language feature.

It occurred to me that a scripting language with a syntax like ABC but with access to the Amoeba system calls would fill the need. I realized that it would be foolish to write an Amoeba-specific language, so I decided that I needed a language that was generally extensible.

During the 1989 Christmas holidays, I had a lot of time on my hand, so I decided to give it a try. During the next year, while still mostly working on it in my own time, Python was used in the Amoeba project with increasing success, and the feedback from colleagues made me add many early improvements.

In February 1991, after just over a year of development, I decided to post to USENET. The rest is in the `Misc/HISTORY` file.

### 1.1.5 What is Python good for?

Python is a high-level general-purpose programming language that can be applied to many different classes of problems.

The language comes with a large standard library that covers areas such as string processing (regular expressions, Unicode, calculating differences between files), Internet protocols (HTTP, FTP, SMTP, XML-RPC, POP, IMAP, CGI programming), software engineering (unit testing, logging, profiling, parsing Python code), and operating system interfaces (system calls, filesystems, TCP/IP sockets). Look at the table of contents for *library-index* to get an idea of what's available. A wide variety of third-party extensions are also available. Consult the [Python Package Index](#) to find packages of interest to you.

### 1.1.6 How does the Python version numbering scheme work?

Python versions are numbered A.B.C or A.B. A is the major version number – it is only incremented for really major changes in the language. B is the minor version number, incremented for less earth-shattering changes. C is the micro-level – it is incremented for each bugfix release. See [PEP 6](#) for more information about bugfix releases.

Not all releases are bugfix releases. In the run-up to a new major release, a series of development releases are made, denoted as alpha, beta, or release candidate. Alphas are early releases in which interfaces aren't yet finalized; it's not unexpected to see an interface change between two alpha releases. Betas are more stable, preserving existing interfaces but possibly adding new modules, and release candidates are frozen, making no changes except as needed to fix critical bugs.

Alpha, beta and release candidate versions have an additional suffix. The suffix for an alpha version is "aN" for some small number N, the suffix for a beta version is "bN" for some small number N, and the suffix for a release candidate version is "cN" for some small number N. In other words, all versions labeled 2.0aN precede the versions labeled 2.0bN, which precede versions labeled 2.0cN, and *those* precede 2.0.

You may also find version numbers with a "+" suffix, e.g. "2.2+". These are unreleased versions, built directly from the Subversion trunk. In practice, after a final minor release is made, the Subversion trunk is incremented to the next minor version, which becomes the "a0" version, e.g. "2.4a0".

See also the documentation for `sys.version`, `sys.hexversion`, and `sys.version_info`.

### 1.1.7 How do I obtain a copy of the Python source?

The latest Python source distribution is always available from [python.org](http://www.python.org/download/), at <http://www.python.org/download/>. The latest development sources can be obtained via anonymous Mercurial access at <http://hg.python.org/cpython>.

The source distribution is a gzipped tar file containing the complete C source, Sphinx-formatted documentation, Python library modules, example programs, and several useful pieces of freely distributable software. The source will compile and run out of the box on most UNIX platforms.

Consult the [Developer FAQ](#) for more information on getting the source code and compiling it.

### 1.1.8 How do I get documentation on Python?

The standard documentation for the current stable version of Python is available at <http://docs.python.org/>. PDF, plain text, and downloadable HTML versions are also available at <http://docs.python.org/download.html>.

The documentation is written in reStructuredText and processed by the [Sphinx documentation tool](#). The reStructuredText source for the documentation is part of the Python source distribution.

### 1.1.9 I've never programmed before. Is there a Python tutorial?

There are numerous tutorials and books available. The standard documentation includes *tutorial-index*.

Consult the [Beginner's Guide](#) to find information for beginning Python programmers, including lists of tutorials.

### 1.1.10 Is there a newsgroup or mailing list devoted to Python?

There is a newsgroup, *comp.lang.python*, and a mailing list, *python-list*. The newsgroup and mailing list are gatewayed into each other – if you can read news it's unnecessary to subscribe to the mailing list. *comp.lang.python* is high-traffic, receiving hundreds of postings every day, and Usenet readers are often more able to cope with this volume.

Announcements of new software releases and events can be found in *comp.lang.python.announce*, a low-traffic moderated list that receives about five postings per day. It's available as the [python-announce mailing list](#).

More info about other mailing lists and newsgroups can be found at <http://www.python.org/community/lists/>.

### 1.1.11 How do I get a beta test version of Python?

Alpha and beta releases are available from <http://www.python.org/download/>. All releases are announced on the *comp.lang.python* and *comp.lang.python.announce* newsgroups and on the Python home page at <http://www.python.org/>; an RSS feed of news is available.

You can also access the development version of Python through Subversion. See <http://docs.python.org/devguide/faq> for details.

### 1.1.12 How do I submit bug reports and patches for Python?

To report a bug or submit a patch, please use the Roundup installation at <http://bugs.python.org/>.

You must have a Roundup account to report bugs; this makes it possible for us to contact you if we have follow-up questions. It will also enable Roundup to send you updates as we act on your bug. If you had previously used SourceForge to report bugs to Python, you can obtain your Roundup password through Roundup's [password reset procedure](#).

For more information on how Python is developed, consult the [Python Developer's Guide](#).

### 1.1.13 Are there any published articles about Python that I can reference?

It's probably best to cite your favorite book about Python.

The very first article about Python was written in 1991 and is now quite outdated.

Guido van Rossum and Jelke de Boer, "Interactively Testing Remote Servers Using the Python Programming Language", CWI Quarterly, Volume 4, Issue 4 (December 1991), Amsterdam, pp 283-303.

### 1.1.14 Are there any books on Python?

Yes, there are many, and more are being published. See the [python.org](http://wiki.python.org/moin/PythonBooks) wiki at <http://wiki.python.org/moin/PythonBooks> for a list.

You can also search online bookstores for "Python" and filter out the Monty Python references; or perhaps search for "Python" and "language".

### 1.1.15 Where in the world is [www.python.org](http://www.python.org) located?

It's currently in Amsterdam, graciously hosted by [XS4ALL](http://XS4ALL). Thanks to Thomas Wouters for his work in arranging [python.org](http://python.org)'s hosting.

### 1.1.16 Why is it called Python?

When he began implementing Python, Guido van Rossum was also reading the published scripts from "Monty Python's Flying Circus", a BBC comedy series from the 1970s. Van Rossum thought he needed a name that was short, unique, and slightly mysterious, so he decided to call the language Python.

### 1.1.17 Do I have to like "Monty Python's Flying Circus"?

No, but it helps. :)

## 1.2 Python in the real world

### 1.2.1 How stable is Python?

Very stable. New, stable releases have been coming out roughly every 6 to 18 months since 1991, and this seems likely to continue. Currently there are usually around 18 months between major releases.

The developers issue "bugfix" releases of older versions, so the stability of existing releases gradually improves. Bugfix releases, indicated by a third component of the version number (e.g. 2.5.3, 2.6.2), are managed for stability; only fixes for known problems are included in a bugfix release, and it's guaranteed that interfaces will remain the same throughout a series of bugfix releases.

The latest stable releases can always be found on the [Python download page](#). There are two recommended production-ready versions at this point in time, because at the moment there are two branches of stable releases: 2.x and 3.x. Python 3.x may be less useful than 2.x, since currently there is more third party software available for Python 2 than for Python 3. Python 2 code will generally not run unchanged in Python 3.

### 1.2.2 How many people are using Python?

There are probably tens of thousands of users, though it's difficult to obtain an exact count.

Python is available for free download, so there are no sales figures, and it's available from many different sites and packaged with many Linux distributions, so download statistics don't tell the whole story either.

The `comp.lang.python` newsgroup is very active, but not all Python users post to the group or even read it.

### 1.2.3 Have any significant projects been done in Python?

See <http://python.org/about/success> for a list of projects that use Python. Consulting the proceedings for [past Python conferences](#) will reveal contributions from many different companies and organizations.

High-profile Python projects include [the Mailman mailing list manager](#) and [the Zope application server](#). Several Linux distributions, most notably [Red Hat](#), have written part or all of their installer and system administration software in Python. Companies that use Python internally include Google, Yahoo, and Lucasfilm Ltd.

### 1.2.4 What new developments are expected for Python in the future?

See <http://www.python.org/dev/peps/> for the Python Enhancement Proposals (PEPs). PEPs are design documents describing a suggested new feature for Python, providing a concise technical specification and a rationale. Look for a PEP titled "Python X.Y Release Schedule", where X.Y is a version that hasn't been publicly released yet.

New development is discussed on [the python-dev mailing list](#).

### 1.2.5 Is it reasonable to propose incompatible changes to Python?

In general, no. There are already millions of lines of Python code around the world, so any change in the language that invalidates more than a very small fraction of existing programs has to be frowned upon. Even if you can provide a conversion program, there's still the problem of updating all documentation; many books have been written about Python, and we don't want to invalidate them all at a single stroke.

Providing a gradual upgrade path is necessary if a feature has to be changed.

**PEP 5** describes the procedure followed for introducing backward-incompatible changes while minimizing disruption for users.

### 1.2.6 Is Python Y2K (Year 2000) Compliant?

As of August, 2003 no major problems have been reported and Y2K compliance seems to be a non-issue.

Python does very few date calculations and for those it does perform relies on the C library functions. Python generally represents times either as seconds since 1970 or as a `(year, month, day, ...)` tuple where the year is expressed with four digits, which makes Y2K bugs unlikely. So as long as your C library is okay, Python should be okay. Of course, it's possible that a particular application written in Python makes assumptions about 2-digit years.

Because Python is available free of charge, there are no absolute guarantees. If there *are* unforeseen problems, liability is the user's problem rather than the developers', and there is nobody you can sue for damages. The Python copyright notice contains the following disclaimer:

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The good news is that *if* you encounter a problem, you have full source available to track it down and fix it. This is one advantage of an open source programming environment.

## 1.2.7 Is Python a good language for beginning programmers?

Yes.

It is still common to start students with a procedural and statically typed language such as Pascal, C, or a subset of C++ or Java. Students may be better served by learning Python as their first language. Python has a very simple and consistent syntax and a large standard library and, most importantly, using Python in a beginning programming course lets students concentrate on important programming skills such as problem decomposition and data type design. With Python, students can be quickly introduced to basic concepts such as loops and procedures. They can probably even work with user-defined objects in their very first course.

For a student who has never programmed before, using a statically typed language seems unnatural. It presents additional complexity that the student must master and slows the pace of the course. The students are trying to learn to think like a computer, decompose problems, design consistent interfaces, and encapsulate data. While learning to use a statically typed language is important in the long term, it is not necessarily the best topic to address in the students' first programming course.

Many other aspects of Python make it a good first language. Like Java, Python has a large standard library so that students can be assigned programming projects very early in the course that *do* something. Assignments aren't restricted to the standard four-function calculator and check balancing programs. By using the standard library, students can gain the satisfaction of working on realistic applications as they learn the fundamentals of programming. Using the standard library also teaches students about code reuse. Third-party modules such as PyGame are also helpful in extending the students' reach.

Python's interactive interpreter enables students to test language features while they're programming. They can keep a window with the interpreter running while they enter their program's source in another window. If they can't remember the methods for a list, they can do something like this:

```
>>> L = []
>>> dir(L)
['append', 'count', 'extend', 'index', 'insert', 'pop', 'remove',
 'reverse', 'sort']
>>> help(L.append)
Help on built-in function append:

append(...)
    L.append(object) -- append object to end
>>> L.append(1)
>>> L
[1]
```

With the interpreter, documentation is never far from the student as he's programming.

There are also good IDEs for Python. IDLE is a cross-platform IDE for Python that is written in Python using Tkinter. PythonWin is a Windows-specific IDE. Emacs users will be happy to know that there is a very good Python mode for Emacs. All of these programming environments provide syntax highlighting, auto-indenting, and access

to the interactive interpreter while coding. Consult <http://www.python.org/editors/> for a full list of Python editing environments.

If you want to discuss Python's use in education, you may be interested in joining [the edu-sig mailing list](#).

## 1.3 Upgrading Python

### 1.3.1 What is this bsddb185 module my application keeps complaining about?

Starting with Python2.3, the distribution includes the *PyBSDDB package* <<http://pybsddb.sf.net/>> as a replacement for the old bsddb module. It includes functions which provide backward compatibility at the API level, but requires a newer version of the underlying [Berkeley DB](#) library. Files created with the older bsddb module can't be opened directly using the new module.

Using your old version of Python and a pair of scripts which are part of Python 2.3 (`db2pickle.py` and `pickle2db.py`, in the `Tools/scripts` directory) you can convert your old database files to the new format. Using your old Python version, run the `db2pickle.py` script to convert it to a pickle, e.g.:

```
python2.2 <pathto>/db2pickley.py database.db database.pck
```

Rename your database file:

```
mv database.db olddatabase.db
```

Now convert the pickle file to a new format database:

```
python <pathto>/pickle2db.py database.db database.pck
```

The precise commands you use will vary depending on the particulars of your installation. For full details about operation of these two scripts check the doc string at the start of each one.

# PROGRAMMING FAQ

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## 2.1 General Questions

### 2.1.1 Is there a source code level debugger with breakpoints, single-stepping, etc.?

Yes.

The `pdb` module is a simple but adequate console-mode debugger for Python. It is part of the standard Python library, and is documented in the [Library Reference Manual](#). You can also write your own debugger by using the code for `pdb` as an example.

The IDLE interactive development environment, which is part of the standard Python distribution (normally available as `Tools/scripts/idle`), includes a graphical debugger. There is documentation for the IDLE debugger at <http://www.python.org/idle/doc/idle2.html#Debugger>.

PythonWin is a Python IDE that includes a GUI debugger based on `pdb`. The Pythonwin debugger colors breakpoints and has quite a few cool features such as debugging non-Pythonwin programs. Pythonwin is available as part of the [Python for Windows Extensions](#) project and as a part of the ActivePython distribution (see <http://www.activestate.com/Products/ActivePython/index.html>).

**Boa Constructor** is an IDE and GUI builder that uses `wxWidgets`. It offers visual frame creation and manipulation, an object inspector, many views on the source like object browsers, inheritance hierarchies, doc string generated html documentation, an advanced debugger, integrated help, and Zope support.

**Eric** is an IDE built on `PyQt` and the `Scintilla` editing component.

`Pydb` is a version of the standard Python debugger `pdb`, modified for use with `DDD` (Data Display Debugger), a popular graphical debugger front end. `Pydb` can be found at <http://bashdb.sourceforge.net/pydb/> and `DDD` can be found at <http://www.gnu.org/software/ddd>.

There are a number of commercial Python IDEs that include graphical debuggers. They include:

- Wing IDE (<http://wingware.com/>)
- Komodo IDE (<http://www.activestate.com/Products/Komodo>)

### 2.1.2 Is there a tool to help find bugs or perform static analysis?

Yes.

`PyChecker` is a static analysis tool that finds bugs in Python source code and warns about code complexity and style. You can get `PyChecker` from <http://pychecker.sf.net>.

`Pylint` is another tool that checks if a module satisfies a coding standard, and also makes it possible to write plug-ins to add a custom feature. In addition to the bug checking that `PyChecker` performs, `Pylint` offers some additional features such as checking line length, whether variable names are well-formed according to your coding standard, whether declared interfaces are fully implemented, and more. [http://www.logilab.org/card/pylint\\_manual](http://www.logilab.org/card/pylint_manual) provides a full list of `Pylint`'s features.

### 2.1.3 How can I create a stand-alone binary from a Python script?

You don't need the ability to compile Python to C code if all you want is a stand-alone program that users can download and run without having to install the Python distribution first. There are a number of tools that determine the set of modules required by a program and bind these modules together with a Python binary to produce a single executable.

One is to use the `freeze` tool, which is included in the Python source tree as `Tools/freeze`. It converts Python byte code to C arrays; a C compiler you can embed all your modules into a new program, which is then linked with the standard Python modules.

It works by scanning your source recursively for import statements (in both forms) and looking for the modules in the standard Python path as well as in the source directory (for built-in modules). It then turns the bytecode for modules written in Python into C code (array initializers that can be turned into code objects using the marshal module) and creates a custom-made config file that only contains those built-in modules which are actually used in the program. It then compiles the generated C code and links it with the rest of the Python interpreter to form a self-contained binary which acts exactly like your script.

Obviously, freeze requires a C compiler. There are several other utilities which don't. One is Thomas Heller's py2exe (Windows only) at

<http://www.py2exe.org/>

Another is Christian Tismer's `SQFREEZE` which appends the byte code to a specially-prepared Python interpreter that can find the byte code in the executable.

Other tools include Fredrik Lundh's `Squeeze` and Anthony Tuininga's `cx_Freeze`.

### 2.1.4 Are there coding standards or a style guide for Python programs?

Yes. The coding style required for standard library modules is documented as

**PEP 8**.

### 2.1.5 My program is too slow. How do I speed it up?

That's a tough one, in general. There are many tricks to speed up Python code; consider rewriting parts in C as a last resort.

In some cases it's possible to automatically translate Python to C or x86 assembly language, meaning that you don't have to modify your code to gain increased speed.

`Pyrex` can compile a slightly modified version of Python code into a C extension, and can be used on many different platforms.

`Psyco` is a just-in-time compiler that translates Python code into x86 assembly language. If you can use it, `Psyco` can provide dramatic speedups for critical functions.

The rest of this answer will discuss various tricks for squeezing a bit more speed out of Python code. *Never* apply any optimization tricks unless you know you need them, after profiling has indicated that a particular function is the heavily executed hot spot in the code. Optimizations almost always make the code less clear, and you shouldn't pay the costs of reduced clarity (increased development time, greater likelihood of bugs) unless the resulting performance benefit is worth it.

There is a page on the wiki devoted to [performance tips](#).

Guido van Rossum has written up an anecdote related to optimization at <http://www.python.org/doc/essays/list2str.html>.

One thing to notice is that function and (especially) method calls are rather expensive; if you have designed a purely OO interface with lots of tiny functions that don't do much more than get or set an instance variable or call another method, you might consider using a more direct way such as directly accessing instance variables. Also see the standard module `profile` which makes it possible to find out where your program is spending most of its time (if you have some patience – the profiling itself can slow your program down by an order of magnitude).

Remember that many standard optimization heuristics you may know from other programming experience may well apply to Python. For example it may be faster to send output to output devices using larger writes rather than smaller ones in order to reduce the overhead of kernel system calls. Thus CGI scripts that write all output in “one shot” may be faster than those that write lots of small pieces of output.

Also, be sure to use Python's core features where appropriate. For example, slicing allows programs to chop up lists and other sequence objects in a single tick of the interpreter's mainloop using highly optimized C implementations. Thus to get the same effect as:

```
L2 = []
for i in range(3):
    L2.append(L1[i])
```

it is much shorter and far faster to use

```
L2 = list(L1[:3]) # "list" is redundant if L1 is a list.
```

Note that the functionally-oriented built-in functions such as `map()`, `zip()`, and friends can be a convenient accelerator for loops that perform a single task. For example to pair the elements of two lists together:

```
>>> zip([1, 2, 3], [4, 5, 6])
[(1, 4), (2, 5), (3, 6)]
```

or to compute a number of sines:

```
>>> map(math.sin, (1, 2, 3, 4))
[0.841470984808, 0.909297426826, 0.14112000806, -0.756802495308]
```

The operation completes very quickly in such cases.

Other examples include the `join()` and `split()` *methods of string objects*. For example if `s1..s7` are large (10K+) strings then `"".join([s1,s2,s3,s4,s5,s6,s7])` may be far faster than the more obvious `s1+s2+s3+s4+s5+s6+s7`, since the “summation” will compute many subexpressions, whereas `join()` does all the copying in one pass. For manipulating strings, use the `replace()` and the `format()` *methods on string objects*. Use regular expressions only when you're not dealing with constant string patterns. You may still use *the old % operations* `string % tuple` and `string % dictionary`.

Be sure to use the `list.sort()` built-in method to do sorting, and see the [sorting mini-HOWTO](#) for examples of moderately advanced usage. `list.sort()` beats other techniques for sorting in all but the most extreme circumstances.

Another common trick is to “push loops into functions or methods.” For example suppose you have a program that runs slowly and you use the profiler to determine that a Python function `ff()` is being called lots of times. If you notice that `ff()`:

```
def ff(x):
    ... # do something with x computing result...
    return result
```

tends to be called in loops like:

```
list = map(ff, oldlist)
```

or:

```
for x in sequence:
    value = ff(x)
    ... # do something with value...
```

then you can often eliminate function call overhead by rewriting `ff()` to:

```
def ffseq(seq):
    resultseq = []
    for x in seq:
        ... # do something with x computing result...
        resultseq.append(result)
    return resultseq
```

and rewrite the two examples to `list = ffseq(oldlist)` and to:

```
for value in ffseq(sequence):
    ... # do something with value...
```

Single calls to `ff(x)` translate to `ffseq([x])[0]` with little penalty. Of course this technique is not always appropriate and there are other variants which you can figure out.

You can gain some performance by explicitly storing the results of a function or method lookup into a local variable. A loop like:

```
for key in token:
    dict[key] = dict.get(key, 0) + 1
```

resolves `dict.get` every iteration. If the method isn't going to change, a slightly faster implementation is:

```
dict_get = dict.get # look up the method once
for key in token:
    dict[key] = dict_get(key, 0) + 1
```

Default arguments can be used to determine values once, at compile time instead of at run time. This can only be done for functions or objects which will not be changed during program execution, such as replacing

```
def degree_sin(deg):
    return math.sin(deg * math.pi / 180.0)
```

with

```
def degree_sin(deg, factor=math.pi/180.0, sin=math.sin):
    return sin(deg * factor)
```

Because this trick uses default arguments for terms which should not be changed, it should only be used when you are not concerned with presenting a possibly confusing API to your users.

## 2.2 Core Language

### 2.2.1 Why am I getting an `UnboundLocalError` when the variable has a value?

It can be a surprise to get the `UnboundLocalError` in previously working code when it is modified by adding an assignment statement somewhere in the body of a function.

This code:

```
>>> x = 10
>>> def bar():
...     print x
>>> bar()
10
```

works, but this code:

```
>>> x = 10
>>> def foo():
...     print x
...     x += 1
```

results in an `UnboundLocalError`:

```
>>> foo()
Traceback (most recent call last):
```

```
...
UnboundLocalError: local variable 'x' referenced before assignment
```

This is because when you make an assignment to a variable in a scope, that variable becomes local to that scope and shadows any similarly named variable in the outer scope. Since the last statement in `foo` assigns a new value to `x`, the compiler recognizes it as a local variable. Consequently when the earlier `print x` attempts to print the uninitialized local variable and an error results.

In the example above you can access the outer scope variable by declaring it global:

```
>>> x = 10
>>> def foo():
...     global x
...     print x
...     x += 1
>>> foo()
10
```

This explicit declaration is required in order to remind you that (unlike the superficially analogous situation with class and instance variables) you are actually modifying the value of the variable in the outer scope:

```
>>> print x
11
```

## 2.2.2 What are the rules for local and global variables in Python?

In Python, variables that are only referenced inside a function are implicitly global. If a variable is assigned a new value anywhere within the function's body, it's assumed to be a local. If a variable is ever assigned a new value inside the function, the variable is implicitly local, and you need to explicitly declare it as 'global'.

Though a bit surprising at first, a moment's consideration explains this. On one hand, requiring `global` for assigned variables provides a bar against unintended side-effects. On the other hand, if `global` was required for all global references, you'd be using `global` all the time. You'd have to declare as global every reference to a built-in function or to a component of an imported module. This clutter would defeat the usefulness of the `global` declaration for identifying side-effects.

## 2.2.3 How do I share global variables across modules?

The canonical way to share information across modules within a single program is to create a special module (often called `config` or `cfg`). Just import the `config` module in all modules of your application; the module then becomes available as a global name. Because there is only one instance of each module, any changes made to the module object get reflected everywhere. For example:

`config.py`:

```
x = 0 # Default value of the 'x' configuration setting
```

`mod.py`:

```
import config
config.x = 1
```

`main.py`:

```
import config
import mod
print config.x
```

Note that using a module is also the basis for implementing the Singleton design pattern, for the same reason.

### 2.2.4 What are the “best practices” for using import in a module?

In general, don't use `from modulename import *`. Doing so clutters the importer's namespace. Some people avoid this idiom even with the few modules that were designed to be imported in this manner. Modules designed in this manner include `Tkinter`, and `threading`.

Import modules at the top of a file. Doing so makes it clear what other modules your code requires and avoids questions of whether the module name is in scope. Using one import per line makes it easy to add and delete module imports, but using multiple imports per line uses less screen space.

It's good practice if you import modules in the following order:

1. standard library modules – e.g. `sys`, `os`, `getopt`, `re`
2. third-party library modules (anything installed in Python's site-packages directory) – e.g. `mx.DateTime`, `ZODB`, `PIL.Image`, etc.
3. locally-developed modules

Never use relative package imports. If you're writing code that's in the `package.sub.m1` module and want to import `package.sub.m2`, do not just write `import m2`, even though it's legal. Write `from package.sub import m2` instead. Relative imports can lead to a module being initialized twice, leading to confusing bugs. See [PEP 328](#) for details.

It is sometimes necessary to move imports to a function or class to avoid problems with circular imports. Gordon McMillan says:

Circular imports are fine where both modules use the “import <module>” form of import. They fail when the 2nd module wants to grab a name out of the first (“from module import name”) and the import is at the top level. That's because names in the 1st are not yet available, because the first module is busy importing the 2nd.

In this case, if the second module is only used in one function, then the import can easily be moved into that function. By the time the import is called, the first module will have finished initializing, and the second module can do its import.

It may also be necessary to move imports out of the top level of code if some of the modules are platform-specific. In that case, it may not even be possible to import all of the modules at the top of the file. In this case, importing the correct modules in the corresponding platform-specific code is a good option.

Only move imports into a local scope, such as inside a function definition, if it's necessary to solve a problem such as avoiding a circular import or are trying to reduce the initialization time of a module. This technique is especially helpful if many of the imports are unnecessary depending on how the program executes. You may also want to move imports into a function if the modules are only ever used in that function. Note that loading a module the first time may be expensive because of the one time initialization of the module, but loading a module multiple times is virtually free, costing only a couple of dictionary lookups. Even if the module name has gone out of scope, the module is probably available in `sys.modules`.

If only instances of a specific class use a module, then it is reasonable to import the module in the class's `__init__` method and then assign the module to an instance variable so that the module is always available (via that instance variable) during the life of the object. Note that to delay an import until the class is instantiated, the import must be inside a method. Putting the import inside the class but outside of any method still causes the import to occur when the module is initialized.

### 2.2.5 How can I pass optional or keyword parameters from one function to another?

Collect the arguments using the `*` and `**` specifiers in the function's parameter list; this gives you the positional arguments as a tuple and the keyword arguments as a dictionary. You can then pass these arguments when calling another function by using `*` and `**`:

```
def f(x, *args, **kwargs):
    ...
    kwargs['width'] = '14.3c'
    ...
    g(x, *args, **kwargs)
```

In the unlikely case that you care about Python versions older than 2.0, use `apply()`:

```
def f(x, *args, **kwargs):
    ...
    kwargs['width'] = '14.3c'
    ...
    apply(g, (x,) + args, kwargs)
```

## 2.2.6 How do I write a function with output parameters (call by reference)?

Remember that arguments are passed by assignment in Python. Since assignment just creates references to objects, there's no alias between an argument name in the caller and callee, and so no call-by-reference per se. You can achieve the desired effect in a number of ways.

1. By returning a tuple of the results:

```
def func2(a, b):
    a = 'new-value'           # a and b are local names
    b = b + 1                 # assigned to new objects
    return a, b              # return new values

x, y = 'old-value', 99
x, y = func2(x, y)
print x, y                   # output: new-value 100
```

This is almost always the clearest solution.

2. By using global variables. This isn't thread-safe, and is not recommended.
3. By passing a mutable (changeable in-place) object:

```
def func1(a):
    a[0] = 'new-value'       # 'a' references a mutable list
    a[1] = a[1] + 1          # changes a shared object

args = ['old-value', 99]
func1(args)
print args[0], args[1]     # output: new-value 100
```

4. By passing in a dictionary that gets mutated:

```
def func3(args):
    args['a'] = 'new-value'   # args is a mutable dictionary
    args['b'] = args['b'] + 1 # change it in-place

args = {'a': 'old-value', 'b': 99}
func3(args)
print args['a'], args['b']
```

5. Or bundle up values in a class instance:

```
class callByRef:
    def __init__(self, **args):
```

```
        for (key, value) in args.items():
            setattr(self, key, value)

def func4(args):
    args.a = 'new-value'           # args is a mutable callByRef
    args.b = args.b + 1           # change object in-place

args = callByRef(a='old-value', b=99)
func4(args)
print args.a, args.b
```

There's almost never a good reason to get this complicated.

Your best choice is to return a tuple containing the multiple results.

### 2.2.7 How do you make a higher order function in Python?

You have two choices: you can use nested scopes or you can use callable objects. For example, suppose you wanted to define `linear(a,b)` which returns a function `f(x)` that computes the value  $a*x+b$ . Using nested scopes:

```
def linear(a, b):
    def result(x):
        return a * x + b
    return result
```

Or using a callable object:

```
class linear:

    def __init__(self, a, b):
        self.a, self.b = a, b

    def __call__(self, x):
        return self.a * x + self.b
```

In both cases,

```
taxes = linear(0.3, 2)
```

gives a callable object where `taxes(10e6) == 0.3 * 10e6 + 2`.

The callable object approach has the disadvantage that it is a bit slower and results in slightly longer code. However, note that a collection of callables can share their signature via inheritance:

```
class exponential(linear):
    # __init__ inherited
    def __call__(self, x):
        return self.a * (x ** self.b)
```

Object can encapsulate state for several methods:

```
class counter:

    value = 0

    def set(self, x):
        self.value = x

    def up(self):
```

```

        self.value = self.value + 1

    def down(self):
        self.value = self.value - 1

```

```

count = counter()
inc, dec, reset = count.up, count.down, count.set

```

Here `inc()`, `dec()` and `reset()` act like functions which share the same counting variable.

## 2.2.8 How do I copy an object in Python?

In general, try `copy.copy()` or `copy.deepcopy()` for the general case. Not all objects can be copied, but most can.

Some objects can be copied more easily. Dictionaries have a `copy()` method:

```
newdict = olddict.copy()
```

Sequences can be copied by slicing:

```
new_l = l[:]
```

## 2.2.9 How can I find the methods or attributes of an object?

For an instance `x` of a user-defined class, `dir(x)` returns an alphabetized list of the names containing the instance attributes and methods and attributes defined by its class.

## 2.2.10 How can my code discover the name of an object?

Generally speaking, it can't, because objects don't really have names. Essentially, assignment always binds a name to a value; The same is true of `def` and `class` statements, but in that case the value is a callable. Consider the following code:

```

class A:
    pass

B = A

a = B()
b = a
print b
<__main__.A instance at 0x16D07CC>
print a
<__main__.A instance at 0x16D07CC>

```

Arguably the class has a name: even though it is bound to two names and invoked through the name `B` the created instance is still reported as an instance of class `A`. However, it is impossible to say whether the instance's name is `a` or `b`, since both names are bound to the same value.

Generally speaking it should not be necessary for your code to “know the names” of particular values. Unless you are deliberately writing introspective programs, this is usually an indication that a change of approach might be beneficial.

In `comp.lang.python`, Fredrik Lundh once gave an excellent analogy in answer to this question:

The same way as you get the name of that cat you found on your porch: the cat (object) itself cannot tell you its name, and it doesn't really care – so the only way to find out what it's called is to ask all your neighbours (namespaces) if it's their cat (object)...

....and don't be surprised if you'll find that it's known by many names, or no name at all!

### 2.2.11 What's up with the comma operator's precedence?

Comma is not an operator in Python. Consider this session:

```
>>> "a" in "b", "a"
(False, 'a')
```

Since the comma is not an operator, but a separator between expressions the above is evaluated as if you had entered:

```
>>> ("a" in "b"), "a"
```

not:

```
>>> "a" in ("b", "a")
```

The same is true of the various assignment operators (=, += etc). They are not truly operators but syntactic delimiters in assignment statements.

### 2.2.12 Is there an equivalent of C's "?:" ternary operator?

Yes, this feature was added in Python 2.5. The syntax would be as follows:

```
[on_true] if [expression] else [on_false]
```

```
x, y = 50, 25
```

```
small = x if x < y else y
```

For versions previous to 2.5 the answer would be 'No'.

In many cases you can mimic `a ? b : c` with `a and b or c`, but there's a flaw: if `b` is zero (or empty, or `None` – anything that tests false) then `c` will be selected instead. In many cases you can prove by looking at the code that this can't happen (e.g. because `b` is a constant or has a type that can never be false), but in general this can be a problem.

Tim Peters (who wishes it was Steve Majewski) suggested the following solution: `(a and [b] or [c])[0]`. Because `[b]` is a singleton list it is never false, so the wrong path is never taken; then applying `[0]` to the whole thing gets the `b` or `c` that you really wanted. Ugly, but it gets you there in the rare cases where it is really inconvenient to rewrite your code using 'if'.

The best course is usually to write a simple `if...else` statement. Another solution is to implement the `?:` operator as a function:

```
def q(cond, on_true, on_false):
    if cond:
        if not isfunction(on_true):
            return on_true
        else:
            return on_true()
    else:
        if not isfunction(on_false):
            return on_false
```

```

else:
    return on_false()

```

In most cases you'll pass `b` and `c` directly: `q(a, b, c)`. To avoid evaluating `b` or `c` when they shouldn't be, encapsulate them within a lambda function, e.g.: `q(a, lambda: b, lambda: c)`.

It has been asked *why* Python has no if-then-else expression. There are several answers: many languages do just fine without one; it can easily lead to less readable code; no sufficiently "Pythonic" syntax has been discovered; a search of the standard library found remarkably few places where using an if-then-else expression would make the code more understandable.

In 2002, **PEP 308** was written proposing several possible syntaxes and the community was asked to vote on the issue. The vote was inconclusive. Most people liked one of the syntaxes, but also hated other syntaxes; many votes implied that people preferred no ternary operator rather than having a syntax they hated.

## 2.2.13 Is it possible to write obfuscated one-liners in Python?

Yes. Usually this is done by nesting `lambda` within `lambda`. See the following three examples, due to Ulf Bartelt:

```

# Primes < 1000
print filter(None, map(lambda y: y * reduce(lambda x, y: x * y != 0,
map(lambda x, y: y % x, range(2, int(pow(y, 0.5) + 1))), 1), range(2, 1000)))

# First 10 Fibonacci numbers
print map(lambda x, f=lambda x, f: (f(x-1, f) + f(x-2, f)) if x > 1 else 1: f(x, f),
range(10))

# Mandelbrot set
print (lambda Ru, Ro, Iu, Io, IM, Sx, Sy: reduce(lambda x, y: x + y, map(lambda y,
Iu=Iu, Io=Io, Ru=Ru, Ro=Ro, Sy=Sy, L=lambda yc, Iu=Iu, Io=Io, Ru=Ru, Ro=Ro, i=IM,
Sx=Sx, Sy=Sy: reduce(lambda x, y: x + y, map(lambda x, xc=Ru, yc=yc, Ru=Ru, Ro=Ro,
i=i, Sx=Sx, F=lambda xc, yc, x, y, k, f=lambda xc, yc, x, y, k, f: (k <= 0) or (x * x + y * y
>= 4.0) or 1 + f(xc, yc, x * x - y * y + xc, 2.0 * x * y + yc, k - 1, f) : f(xc, yc, x, y, k, f) : chr(
64 + F(Ru + x * (Ro - Ru) / Sx, yc, 0, 0, i)), range(Sx)) : L(Iu + y * (Io - Iu) / Sy), range(Sy)
))) (-2.1, 0.7, -1.2, 1.2, 30, 80, 24)
#      \___ ___/ \___ ___/ | | |___ lines on screen
#          V          V | |___ columns on screen
#          |          |___ maximum of "iterations"
#          |          |___ range on y axis
#          |___ range on x axis

```

Don't try this at home, kids!

## 2.3 Numbers and strings

### 2.3.1 How do I specify hexadecimal and octal integers?

To specify an octal digit, precede the octal value with a zero, and then a lower or uppercase "o". For example, to set the variable "a" to the octal value "10" (8 in decimal), type:

```

>>> a = 0o10
>>> a
8

```

Hexadecimal is just as easy. Simply precede the hexadecimal number with a zero, and then a lower or uppercase “x”. Hexadecimal digits can be specified in lower or uppercase. For example, in the Python interpreter:

```
>>> a = 0xa5
>>> a
165
>>> b = 0xB2
>>> b
178
```

### 2.3.2 Why does `-22 // 10` return `-3`?

It’s primarily driven by the desire that `i % j` have the same sign as `j`. If you want that, and also want:

```
i == (i // j) * j + (i % j)
```

then integer division has to return the floor. C also requires that identity to hold, and then compilers that truncate `i // j` need to make `i % j` have the same sign as `i`.

There are few real use cases for `i % j` when `j` is negative. When `j` is positive, there are many, and in virtually all of them it’s more useful for `i % j` to be  $\geq 0$ . If the clock says 10 now, what did it say 200 hours ago? `-190 % 12 == 2` is useful; `-190 % 12 == -10` is a bug waiting to bite.

---

**Note:** On Python 2, `a / b` returns the same as `a // b` if `__future__.division` is not in effect. This is also known as “classic” division.

---

### 2.3.3 How do I convert a string to a number?

For integers, use the built-in `int()` type constructor, e.g. `int('144') == 144`. Similarly, `float()` converts to floating-point, e.g. `float('144') == 144.0`.

By default, these interpret the number as decimal, so that `int('0144') == 144` and `int('0x144')` raises `ValueError`. `int(string, base)` takes the base to convert from as a second optional argument, so `int('0x144', 16) == 324`. If the base is specified as 0, the number is interpreted using Python’s rules: a leading ‘0’ indicates octal, and ‘0x’ indicates a hex number.

Do not use the built-in function `eval()` if all you need is to convert strings to numbers. `eval()` will be significantly slower and it presents a security risk: someone could pass you a Python expression that might have unwanted side effects. For example, someone could pass `__import__('os').system("rm -rf $HOME")` which would erase your home directory.

`eval()` also has the effect of interpreting numbers as Python expressions, so that e.g. `eval('09')` gives a syntax error because Python regards numbers starting with ‘0’ as octal (base 8).

### 2.3.4 How do I convert a number to a string?

To convert, e.g., the number 144 to the string ‘144’, use the built-in type constructor `str()`. If you want a hexadecimal or octal representation, use the built-in functions `hex()` or `oct()`. For fancy formatting, see the *formatstrings* section, e.g. `"{:04d}".format(144)` yields ‘0144’ and `"{: .3f}".format(1/3)` yields ‘0.333’. You may also use *the % operator* on strings. See the library reference manual for details.

### 2.3.5 How do I modify a string in place?

You can't, because strings are immutable. If you need an object with this ability, try converting the string to a list or use the array module:

```
>>> s = "Hello, world"
>>> a = list(s)
>>> print a
['H', 'e', 'l', 'l', 'o', ',', ' ', 'w', 'o', 'r', 'l', 'd']
>>> a[7:] = list("there!")
>>> ''.join(a)
'Hello, there!'

>>> import array
>>> a = array.array('c', s)
>>> print a
array('c', 'Hello, world')
>>> a[0] = 'y' ; print a
array('c', 'yello world')
>>> a.tostring()
'yello, world'
```

### 2.3.6 How do I use strings to call functions/methods?

There are various techniques.

- The best is to use a dictionary that maps strings to functions. The primary advantage of this technique is that the strings do not need to match the names of the functions. This is also the primary technique used to emulate a case construct:

```
def a():
    pass
```

```
def b():
    pass
```

```
dispatch = {'go': a, 'stop': b} # Note lack of parens for funcs
```

```
dispatch[get_input()]() # Note trailing parens to call function
```

- Use the built-in function `getattr()`:

```
import foo
getattr(foo, 'bar')()
```

Note that `getattr()` works on any object, including classes, class instances, modules, and so on.

This is used in several places in the standard library, like this:

```
class Foo:
    def do_foo(self):
        ...

    def do_bar(self):
        ...
```

```
f = getattr(foo_instance, 'do_' + opname)
f()
```

- Use `locals()` or `eval()` to resolve the function name:

```
def myFunc():
    print "hello"

fname = "myFunc"

f = locals()[fname]
f()

f = eval(fname)
f()
```

Note: Using `eval()` is slow and dangerous. If you don't have absolute control over the contents of the string, someone could pass a string that resulted in an arbitrary function being executed.

### 2.3.7 Is there an equivalent to Perl's `chomp()` for removing trailing newlines from strings?

Starting with Python 2.2, you can use `S.rstrip("\r\n")` to remove all occurrences of any line terminator from the end of the string `S` without removing other trailing whitespace. If the string `S` represents more than one line, with several empty lines at the end, the line terminators for all the blank lines will be removed:

```
>>> lines = ("line 1 \r\n"
...         "\r\n"
...         "\r\n")
>>> lines.rstrip("\n\r")
'line 1 '
```

Since this is typically only desired when reading text one line at a time, using `S.rstrip()` this way works well.

For older versions of Python, there are two partial substitutes:

- If you want to remove all trailing whitespace, use the `rstrip()` method of string objects. This removes all trailing whitespace, not just a single newline.
- Otherwise, if there is only one line in the string `S`, use `S.splitlines()[0]`.

### 2.3.8 Is there a `scanf()` or `sscanf()` equivalent?

Not as such.

For simple input parsing, the easiest approach is usually to split the line into whitespace-delimited words using the `split()` method of string objects and then convert decimal strings to numeric values using `int()` or `float()`. `split()` supports an optional “sep” parameter which is useful if the line uses something other than whitespace as a separator.

For more complicated input parsing, regular expressions are more powerful than C's `scanf()` and better suited for the task.

### 2.3.9 What does ‘UnicodeError: ASCII [decoding,encoding] error: ordinal not in range(128)’ mean?

This error indicates that your Python installation can handle only 7-bit ASCII strings. There are a couple ways to fix or work around the problem.

If your programs must handle data in arbitrary character set encodings, the environment the application runs in will generally identify the encoding of the data it is handing you. You need to convert the input to Unicode data using that encoding. For example, a program that handles email or web input will typically find character set encoding information in Content-Type headers. This can then be used to properly convert input data to Unicode. Assuming the string referred to by `value` is encoded as UTF-8:

```
value = unicode(value, "utf-8")
```

will return a Unicode object. If the data is not correctly encoded as UTF-8, the above call will raise a `UnicodeError` exception.

If you only want strings converted to Unicode which have non-ASCII data, you can try converting them first assuming an ASCII encoding, and then generate Unicode objects if that fails:

```
try:
    x = unicode(value, "ascii")
except UnicodeError:
    value = unicode(value, "utf-8")
else:
    # value was valid ASCII data
    pass
```

It’s possible to set a default encoding in a file called `sitecustomize.py` that’s part of the Python library. However, this isn’t recommended because changing the Python-wide default encoding may cause third-party extension modules to fail.

Note that on Windows, there is an encoding known as “mbcs”, which uses an encoding specific to your current locale. In many cases, and particularly when working with COM, this may be an appropriate default encoding to use.

## 2.4 Sequences (Tuples/Lists)

### 2.4.1 How do I convert between tuples and lists?

The type constructor `tuple(seq)` converts any sequence (actually, any iterable) into a tuple with the same items in the same order.

For example, `tuple([1, 2, 3])` yields `(1, 2, 3)` and `tuple('abc')` yields `('a', 'b', 'c')`. If the argument is a tuple, it does not make a copy but returns the same object, so it is cheap to call `tuple()` when you aren’t sure that an object is already a tuple.

The type constructor `list(seq)` converts any sequence or iterable into a list with the same items in the same order. For example, `list((1, 2, 3))` yields `[1, 2, 3]` and `list('abc')` yields `['a', 'b', 'c']`. If the argument is a list, it makes a copy just like `seq[:]` would.

### 2.4.2 What’s a negative index?

Python sequences are indexed with positive numbers and negative numbers. For positive numbers 0 is the first index 1 is the second index and so forth. For negative indices -1 is the last index and -2 is the penultimate (next to last) index and so forth. Think of `seq[-n]` as the same as `seq[len(seq)-n]`.

Using negative indices can be very convenient. For example `S[:-1]` is all of the string except for its last character, which is useful for removing the trailing newline from a string.

### 2.4.3 How do I iterate over a sequence in reverse order?

Use the `reversed()` built-in function, which is new in Python 2.4:

```
for x in reversed(sequence):
    ... # do something with x...
```

This won't touch your original sequence, but build a new copy with reversed order to iterate over.

With Python 2.3, you can use an extended slice syntax:

```
for x in sequence[::-1]:
    ... # do something with x...
```

### 2.4.4 How do you remove duplicates from a list?

See the Python Cookbook for a long discussion of many ways to do this:

<http://aspn.activestate.com/ASPN/Cookbook/Python/Recipe/52560>

If you don't mind reordering the list, sort it and then scan from the end of the list, deleting duplicates as you go:

```
if mylist:
    mylist.sort()
    last = mylist[-1]
    for i in range(len(mylist)-2, -1, -1):
        if last == mylist[i]:
            del mylist[i]
        else:
            last = mylist[i]
```

If all elements of the list may be used as dictionary keys (i.e. they are all hashable) this is often faster

```
d = {}
for x in mylist:
    d[x] = 1
mylist = list(d.keys())
```

In Python 2.5 and later, the following is possible instead:

```
mylist = list(set(mylist))
```

This converts the list into a set, thereby removing duplicates, and then back into a list.

### 2.4.5 How do you make an array in Python?

Use a list:

```
["this", 1, "is", "an", "array"]
```

Lists are equivalent to C or Pascal arrays in their time complexity; the primary difference is that a Python list can contain objects of many different types.

The `array` module also provides methods for creating arrays of fixed types with compact representations, but they are slower to index than lists. Also note that the Numeric extensions and others define array-like structures with various characteristics as well.

To get Lisp-style linked lists, you can emulate cons cells using tuples:

```
lisp_list = ("like", ("this", ("example", None) ) )
```

If mutability is desired, you could use lists instead of tuples. Here the analogue of lisp car is `lisp_list[0]` and the analogue of cdr is `lisp_list[1]`. Only do this if you're sure you really need to, because it's usually a lot slower than using Python lists.

## 2.4.6 How do I create a multidimensional list?

You probably tried to make a multidimensional array like this:

```
A = [[None] * 2] * 3
```

This looks correct if you print it:

```
>>> A
[[None, None], [None, None], [None, None]]
```

But when you assign a value, it shows up in multiple places:

```
>>> A[0][0] = 5
>>> A
[[5, None], [5, None], [5, None]]
```

The reason is that replicating a list with `*` doesn't create copies, it only creates references to the existing objects. The `*3` creates a list containing 3 references to the same list of length two. Changes to one row will show in all rows, which is almost certainly not what you want.

The suggested approach is to create a list of the desired length first and then fill in each element with a newly created list:

```
A = [None] * 3
for i in range(3):
    A[i] = [None] * 2
```

This generates a list containing 3 different lists of length two. You can also use a list comprehension:

```
w, h = 2, 3
A = [[None] * w for i in range(h)]
```

Or, you can use an extension that provides a matrix datatype; `Numeric Python` is the best known.

## 2.4.7 How do I apply a method to a sequence of objects?

Use a list comprehension:

```
result = [obj.method() for obj in mylist]
```

More generically, you can try the following function:

```
def method_map(objects, method, arguments):
    """method_map([a,b], "meth", (1,2)) gives [a.meth(1,2), b.meth(1,2)]"""
    nobjects = len(objects)
    methods = map(getattr, objects, [method]*nobjects)
    return map(apply, methods, [arguments]*nobjects)
```

## 2.5 Dictionaries

### 2.5.1 How can I get a dictionary to display its keys in a consistent order?

You can't. Dictionaries store their keys in an unpredictable order, so the display order of a dictionary's elements will be similarly unpredictable.

This can be frustrating if you want to save a printable version to a file, make some changes and then compare it with some other printed dictionary. In this case, use the `pprint` module to pretty-print the dictionary; the items will be presented in order sorted by the key.

A more complicated solution is to subclass `dict` to create a `SortedDict` class that prints itself in a predictable order. Here's one simpleminded implementation of such a class:

```
class SortedDict(dict):
    def __repr__(self):
        keys = sorted(self.keys())
        result = ("{!r}: {!r}".format(k, self[k]) for k in keys)
        return "{{{}}}".format(", ".join(result))

    __str__ = __repr__
```

This will work for many common situations you might encounter, though it's far from a perfect solution. The largest flaw is that if some values in the dictionary are also dictionaries, their values won't be presented in any particular order.

### 2.5.2 I want to do a complicated sort: can you do a Schwartzian Transform in Python?

The technique, attributed to Randal Schwartz of the Perl community, sorts the elements of a list by a metric which maps each element to its "sort value". In Python, just use the `key` argument for the `sort()` method:

```
Isorted = L[:]
Isorted.sort(key=lambda s: int(s[10:15]))
```

The `key` argument is new in Python 2.4, for older versions this kind of sorting is quite simple to do with list comprehensions. To sort a list of strings by their uppercase values:

```
tmp1 = [(x.upper(), x) for x in L] # Schwartzian transform
tmp1.sort()
Unsorted = [x[1] for x in tmp1]
```

To sort by the integer value of a subfield extending from positions 10-15 in each string:

```
tmp2 = [(int(s[10:15]), s) for s in L] # Schwartzian transform
tmp2.sort()
Isorted = [x[1] for x in tmp2]
```

Note that `Isorted` may also be computed by

```
def intfield(s):
    return int(s[10:15])

def Icmp(s1, s2):
    return cmp(intfield(s1), intfield(s2))
```

```
Isorted = L[:]
Isorted.sort(Icmp)
```

but since this method calls `intfield()` many times for each element of `L`, it is slower than the Schwartzian Transform.

### 2.5.3 How can I sort one list by values from another list?

Merge them into a single list of tuples, sort the resulting list, and then pick out the element you want.

```
>>> list1 = ["what", "I'm", "sorting", "by"]
>>> list2 = ["something", "else", "to", "sort"]
>>> pairs = zip(list1, list2)
>>> pairs
[('what', 'something'), ('I'm', 'else'), ('sorting', 'to'), ('by', 'sort')]
>>> pairs.sort()
>>> result = [ x[1] for x in pairs ]
>>> result
['else', 'sort', 'to', 'something']
```

An alternative for the last step is:

```
>>> result = []
>>> for p in pairs: result.append(p[1])
```

If you find this more legible, you might prefer to use this instead of the final list comprehension. However, it is almost twice as slow for long lists. Why? First, the `append()` operation has to reallocate memory, and while it uses some tricks to avoid doing that each time, it still has to do it occasionally, and that costs quite a bit. Second, the expression “`result.append`” requires an extra attribute lookup, and third, there’s a speed reduction from having to make all those function calls.

## 2.6 Objects

### 2.6.1 What is a class?

A class is the particular object type created by executing a class statement. Class objects are used as templates to create instance objects, which embody both the data (attributes) and code (methods) specific to a datatype.

A class can be based on one or more other classes, called its base class(es). It then inherits the attributes and methods of its base classes. This allows an object model to be successively refined by inheritance. You might have a generic `Mailbox` class that provides basic accessor methods for a mailbox, and subclasses such as `MboxMailbox`, `MaildirMailbox`, `OutlookMailbox` that handle various specific mailbox formats.

### 2.6.2 What is a method?

A method is a function on some object `x` that you normally call as `x.name(arguments...)`. Methods are defined as functions inside the class definition:

```
class C:
    def meth (self, arg):
        return arg * 2 + self.attribute
```

### 2.6.3 What is self?

Self is merely a conventional name for the first argument of a method. A method defined as `meth(self, a, b, c)` should be called as `x.meth(a, b, c)` for some instance `x` of the class in which the definition occurs; the called method will think it is called as `meth(x, a, b, c)`.

See also *Why must 'self' be used explicitly in method definitions and calls?*.

### 2.6.4 How do I check if an object is an instance of a given class or of a subclass of it?

Use the built-in function `isinstance(obj, cls)`. You can check if an object is an instance of any of a number of classes by providing a tuple instead of a single class, e.g. `isinstance(obj, (class1, class2, ...))`, and can also check whether an object is one of Python's built-in types, e.g. `isinstance(obj, str)` or `isinstance(obj, (int, long, float, complex))`.

Note that most programs do not use `isinstance()` on user-defined classes very often. If you are developing the classes yourself, a more proper object-oriented style is to define methods on the classes that encapsulate a particular behaviour, instead of checking the object's class and doing a different thing based on what class it is. For example, if you have a function that does something:

```
def search(obj):
    if isinstance(obj, Mailbox):
        # ... code to search a mailbox
    elif isinstance(obj, Document):
        # ... code to search a document
    elif ...
```

A better approach is to define a `search()` method on all the classes and just call it:

```
class Mailbox:
    def search(self):
        # ... code to search a mailbox

class Document:
    def search(self):
        # ... code to search a document

obj.search()
```

### 2.6.5 What is delegation?

Delegation is an object oriented technique (also called a design pattern). Let's say you have an object `x` and want to change the behaviour of just one of its methods. You can create a new class that provides a new implementation of the method you're interested in changing and delegates all other methods to the corresponding method of `x`.

Python programmers can easily implement delegation. For example, the following class implements a class that behaves like a file but converts all written data to uppercase:

```
class UpperOut:

    def __init__(self, outfile):
        self._outfile = outfile

    def write(self, s):
```

```

self._outfile.write(s.upper())

def __getattr__(self, name):
    return getattr(self._outfile, name)

```

Here the `UpperOut` class redefines the `write()` method to convert the argument string to uppercase before calling the underlying `self._outfile.write()` method. All other methods are delegated to the underlying `self._outfile` object. The delegation is accomplished via the `__getattr__` method; consult *the language reference* for more information about controlling attribute access.

Note that for more general cases delegation can get trickier. When attributes must be set as well as retrieved, the class must define a `__setattr__()` method too, and it must do so carefully. The basic implementation of `__setattr__()` is roughly equivalent to the following:

```

class X:
    ...
    def __setattr__(self, name, value):
        self.__dict__[name] = value
    ...

```

Most `__setattr__()` implementations must modify `self.__dict__` to store local state for `self` without causing an infinite recursion.

## 2.6.6 How do I call a method defined in a base class from a derived class that overrides it?

If you're using new-style classes, use the built-in `super()` function:

```

class Derived(Base):
    def meth(self):
        super(Derived, self).meth()

```

If you're using classic classes: For a class definition such as `class Derived(Base): ...` you can call method `meth()` defined in `Base` (or one of `Base`'s base classes) as `Base.meth(self, arguments...)`. Here, `Base.meth` is an unbound method, so you need to provide the `self` argument.

## 2.6.7 How can I organize my code to make it easier to change the base class?

You could define an alias for the base class, assign the real base class to it before your class definition, and use the alias throughout your class. Then all you have to change is the value assigned to the alias. Incidentally, this trick is also handy if you want to decide dynamically (e.g. depending on availability of resources) which base class to use. Example:

```

BaseAlias = <real base class>

class Derived(BaseAlias):
    def meth(self):
        BaseAlias.meth(self)
    ...

```

## 2.6.8 How do I create static class data and static class methods?

Both static data and static methods (in the sense of C++ or Java) are supported in Python.

For static data, simply define a class attribute. To assign a new value to the attribute, you have to explicitly use the class name in the assignment:

```
class C:
    count = 0    # number of times C.__init__ called

    def __init__(self):
        C.count = C.count + 1

    def getcount(self):
        return C.count    # or return self.count
```

`c.count` also refers to `C.count` for any `c` such that `isinstance(c, C)` holds, unless overridden by `c` itself or by some class on the base-class search path from `c.__class__` back to `C`.

Caution: within a method of `C`, an assignment like `self.count = 42` creates a new and unrelated instance named “count” in `self`’s own dict. Rebinding of a class-static data name must always specify the class whether inside a method or not:

```
C.count = 314
```

Static methods are possible since Python 2.2:

```
class C:
    def static(arg1, arg2, arg3):
        # No 'self' parameter!
        ...
    static = staticmethod(static)
```

With Python 2.4’s decorators, this can also be written as

```
class C:
    @staticmethod
    def static(arg1, arg2, arg3):
        # No 'self' parameter!
        ...
```

However, a far more straightforward way to get the effect of a static method is via a simple module-level function:

```
def getcount():
    return C.count
```

If your code is structured so as to define one class (or tightly related class hierarchy) per module, this supplies the desired encapsulation.

### 2.6.9 How can I overload constructors (or methods) in Python?

This answer actually applies to all methods, but the question usually comes up first in the context of constructors.

In C++ you’d write

```
class C {
    C() { cout << "No arguments\n"; }
    C(int i) { cout << "Argument is " << i << "\n"; }
}
```

In Python you have to write a single constructor that catches all cases using default arguments. For example:

```
class C:
    def __init__(self, i=None):
        if i is None:
```

```

    print "No arguments"
else:
    print "Argument is", i

```

This is not entirely equivalent, but close enough in practice.

You could also try a variable-length argument list, e.g.

```

def __init__(self, *args):
    ...

```

The same approach works for all method definitions.

### 2.6.10 I try to use `__spam` and I get an error about `__SomeClassName__spam`.

Variable names with double leading underscores are “mangled” to provide a simple but effective way to define class private variables. Any identifier of the form `__spam` (at least two leading underscores, at most one trailing underscore) is textually replaced with `__classname__spam`, where `classname` is the current class name with any leading underscores stripped.

This doesn’t guarantee privacy: an outside user can still deliberately access the “`__classname__spam`” attribute, and private values are visible in the object’s `__dict__`. Many Python programmers never bother to use private variable names at all.

### 2.6.11 My class defines `__del__` but it is not called when I delete the object.

There are several possible reasons for this.

The `del` statement does not necessarily call `__del__()` – it simply decrements the object’s reference count, and if this reaches zero `__del__()` is called.

If your data structures contain circular links (e.g. a tree where each child has a parent reference and each parent has a list of children) the reference counts will never go back to zero. Once in a while Python runs an algorithm to detect such cycles, but the garbage collector might run some time after the last reference to your data structure vanishes, so your `__del__()` method may be called at an inconvenient and random time. This is inconvenient if you’re trying to reproduce a problem. Worse, the order in which object’s `__del__()` methods are executed is arbitrary. You can run `gc.collect()` to force a collection, but there *are* pathological cases where objects will never be collected.

Despite the cycle collector, it’s still a good idea to define an explicit `close()` method on objects to be called whenever you’re done with them. The `close()` method can then remove attributes that refer to subobjects. Don’t call `__del__()` directly – `__del__()` should call `close()` and `close()` should make sure that it can be called more than once for the same object.

Another way to avoid cyclical references is to use the `weakref` module, which allows you to point to objects without incrementing their reference count. Tree data structures, for instance, should use weak references for their parent and sibling references (if they need them!).

If the object has ever been a local variable in a function that caught an expression in an `except` clause, chances are that a reference to the object still exists in that function’s stack frame as contained in the stack trace. Normally, calling `sys.exc_clear()` will take care of this by clearing the last recorded exception.

Finally, if your `__del__()` method raises an exception, a warning message is printed to `sys.stderr`.

### 2.6.12 How do I get a list of all instances of a given class?

Python does not keep track of all instances of a class (or of a built-in type). You can program the class’s constructor to keep track of all instances by keeping a list of weak references to each instance.

## 2.7 Modules

### 2.7.1 How do I create a .pyc file?

When a module is imported for the first time (or when the source is more recent than the current compiled file) a `.pyc` file containing the compiled code should be created in the same directory as the `.py` file.

One reason that a `.pyc` file may not be created is permissions problems with the directory. This can happen, for example, if you develop as one user but run as another, such as if you are testing with a web server. Creation of a `.pyc` file is automatic if you're importing a module and Python has the ability (permissions, free space, etc...) to write the compiled module back to the directory.

Running Python on a top level script is not considered an import and no `.pyc` will be created. For example, if you have a top-level module `abc.py` that imports another module `xyz.py`, when you run `abc`, `xyz.pyc` will be created since `xyz` is imported, but no `abc.pyc` file will be created since `abc.py` isn't being imported.

If you need to create `abc.pyc` – that is, to create a `.pyc` file for a module that is not imported – you can, using the `py_compile` and `compileall` modules.

The `py_compile` module can manually compile any module. One way is to use the `compile()` function in that module interactively:

```
>>> import py_compile
>>> py_compile.compile('abc.py')
```

This will write the `.pyc` to the same location as `abc.py` (or you can override that with the optional parameter `cfile`).

You can also automatically compile all files in a directory or directories using the `compileall` module. You can do it from the shell prompt by running `compileall.py` and providing the path of a directory containing Python files to compile:

```
python -m compileall .
```

### 2.7.2 How do I find the current module name?

A module can find out its own module name by looking at the predefined global variable `__name__`. If this has the value `'__main__'`, the program is running as a script. Many modules that are usually used by importing them also provide a command-line interface or a self-test, and only execute this code after checking `__name__`:

```
def main():
    print 'Running test...'
    ...

if __name__ == '__main__':
    main()
```

### 2.7.3 How can I have modules that mutually import each other?

Suppose you have the following modules:

foo.py:

```
from bar import bar_var
foo_var = 1
```

bar.py:

```
from foo import foo_var
bar_var = 2
```

The problem is that the interpreter will perform the following steps:

- main imports foo
- Empty globals for foo are created
- foo is compiled and starts executing
- foo imports bar
- Empty globals for bar are created
- bar is compiled and starts executing
- bar imports foo (which is a no-op since there already is a module named foo)
- `bar.foo_var = foo.foo_var`

The last step fails, because Python isn't done with interpreting `foo` yet and the global symbol dictionary for `foo` is still empty.

The same thing happens when you use `import foo`, and then try to access `foo.foo_var` in global code.

There are (at least) three possible workarounds for this problem.

Guido van Rossum recommends avoiding all uses of `from <module> import ...`, and placing all code inside functions. Initializations of global variables and class variables should use constants or built-in functions only. This means everything from an imported module is referenced as `<module>.<name>`.

Jim Roskind suggests performing steps in the following order in each module:

- exports (globals, functions, and classes that don't need imported base classes)
- `import` statements
- active code (including globals that are initialized from imported values).

van Rossum doesn't like this approach much because the imports appear in a strange place, but it does work.

Matthias Urlichs recommends restructuring your code so that the recursive import is not necessary in the first place.

These solutions are not mutually exclusive.

## 2.7.4 `__import__('x.y.z')` returns `<module 'x'>`; how do I get `z`?

Try:

```
__import__('x.y.z').y.z
```

For more realistic situations, you may have to do something like

```
m = __import__(s)
for i in s.split(".")[1:]:
    m = getattr(m, i)
```

See `importlib` for a convenience function called `import_module()`.

## 2.7.5 When I edit an imported module and reimport it, the changes don't show up. Why does this happen?

For reasons of efficiency as well as consistency, Python only reads the module file on the first time a module is imported. If it didn't, in a program consisting of many modules where each one imports the same basic module, the basic module would be parsed and re-parsed many times. To force rereading of a changed module, do this:

```
import modname
reload(modname)
```

Warning: this technique is not 100% fool-proof. In particular, modules containing statements like

```
from modname import some_objects
```

will continue to work with the old version of the imported objects. If the module contains class definitions, existing class instances will *not* be updated to use the new class definition. This can result in the following paradoxical behaviour:

```
>>> import cls
>>> c = cls.C()                # Create an instance of C
>>> reload(cls)
<module 'cls' from 'cls.pyc'>
>>> isinstance(c, cls.C)      # isinstance is false?!?
False
```

The nature of the problem is made clear if you print out the class objects:

```
>>> c.__class__
<class cls.C at 0x7352a0>
>>> cls.C
<class cls.C at 0x4198d0>
```

# DESIGN AND HISTORY FAQ

## 3.1 Why does Python use indentation for grouping of statements?

Guido van Rossum believes that using indentation for grouping is extremely elegant and contributes a lot to the clarity of the average Python program. Most people learn to love this feature after a while.

Since there are no begin/end brackets there cannot be a disagreement between grouping perceived by the parser and the human reader. Occasionally C programmers will encounter a fragment of code like this:

```
if (x <= y)
    x++;
    y--;
z++;
```

Only the `x++` statement is executed if the condition is true, but the indentation leads you to believe otherwise. Even experienced C programmers will sometimes stare at it a long time wondering why `y` is being decremented even for `x > y`.

Because there are no begin/end brackets, Python is much less prone to coding-style conflicts. In C there are many different ways to place the braces. If you're used to reading and writing code that uses one style, you will feel at least slightly uneasy when reading (or being required to write) another style.

Many coding styles place begin/end brackets on a line by themselves. This makes programs considerably longer and wastes valuable screen space, making it harder to get a good overview of a program. Ideally, a function should fit on one screen (say, 20-30 lines). 20 lines of Python can do a lot more work than 20 lines of C. This is not solely due to the lack of begin/end brackets – the lack of declarations and the high-level data types are also responsible – but the indentation-based syntax certainly helps.

## 3.2 Why am I getting strange results with simple arithmetic operations?

See the next question.

## 3.3 Why are floating point calculations so inaccurate?

People are often very surprised by results like this:

```
>>> 1.2 - 1.0
0.19999999999999996
```

and think it is a bug in Python. It's not. This has nothing to do with Python, but with how the underlying C platform handles floating point numbers, and ultimately with the inaccuracies introduced when writing down numbers as a string of a fixed number of digits.

The internal representation of floating point numbers uses a fixed number of binary digits to represent a decimal number. Some decimal numbers can't be represented exactly in binary, resulting in small roundoff errors.

In decimal math, there are many numbers that can't be represented with a fixed number of decimal digits, e.g.  $1/3 = 0.3333333333\dots$

In base 2,  $1/2 = 0.1$ ,  $1/4 = 0.01$ ,  $1/8 = 0.001$ , etc.  $.2$  equals  $2/10$  equals  $1/5$ , resulting in the binary fractional number  $0.001100110011001\dots$

Floating point numbers only have 32 or 64 bits of precision, so the digits are cut off at some point, and the resulting number is  $0.19999999999999996$  in decimal, not  $0.2$ .

A floating point number's `repr()` function prints as many digits are necessary to make `eval(repr(f)) == f` true for any float `f`. The `str()` function prints fewer digits and this often results in the more sensible number that was probably intended:

```
>>> 1.1 - 0.9
0.20000000000000007
>>> print 1.1 - 0.9
0.2
```

One of the consequences of this is that it is error-prone to compare the result of some computation to a float with `==`. Tiny inaccuracies may mean that `==` fails. Instead, you have to check that the difference between the two numbers is less than a certain threshold:

```
epsilon = 0.0000000000001 # Tiny allowed error
expected_result = 0.4

if expected_result-epsilon <= computation() <= expected_result+epsilon:
    ...
```

Please see the chapter on *floating point arithmetic* in the Python tutorial for more information.

## 3.4 Why are Python strings immutable?

There are several advantages.

One is performance: knowing that a string is immutable means we can allocate space for it at creation time, and the storage requirements are fixed and unchanging. This is also one of the reasons for the distinction between tuples and lists.

Another advantage is that strings in Python are considered as “elemental” as numbers. No amount of activity will change the value `8` to anything else, and in Python, no amount of activity will change the string “eight” to anything else.

## 3.5 Why must ‘self’ be used explicitly in method definitions and calls?

The idea was borrowed from Modula-3. It turns out to be very useful, for a variety of reasons.

First, it's more obvious that you are using a method or instance attribute instead of a local variable. Reading `self.x` or `self.meth()` makes it absolutely clear that an instance variable or method is used even if you don't know the

class definition by heart. In C++, you can sort of tell by the lack of a local variable declaration (assuming globals are rare or easily recognizable) – but in Python, there are no local variable declarations, so you’d have to look up the class definition to be sure. Some C++ and Java coding standards call for instance attributes to have an `m_` prefix, so this explicitness is still useful in those languages, too.

Second, it means that no special syntax is necessary if you want to explicitly reference or call the method from a particular class. In C++, if you want to use a method from a base class which is overridden in a derived class, you have to use the `::` operator – in Python you can write `baseclass.methodname(self, <argument list>)`. This is particularly useful for `__init__()` methods, and in general in cases where a derived class method wants to extend the base class method of the same name and thus has to call the base class method somehow.

Finally, for instance variables it solves a syntactic problem with assignment: since local variables in Python are (by definition!) those variables to which a value is assigned in a function body (and that aren’t explicitly declared global), there has to be some way to tell the interpreter that an assignment was meant to assign to an instance variable instead of to a local variable, and it should preferably be syntactic (for efficiency reasons). C++ does this through declarations, but Python doesn’t have declarations and it would be a pity having to introduce them just for this purpose. Using the explicit `self.var` solves this nicely. Similarly, for using instance variables, having to write `self.var` means that references to unqualified names inside a method don’t have to search the instance’s directories. To put it another way, local variables and instance variables live in two different namespaces, and you need to tell Python which namespace to use.

## 3.6 Why can’t I use an assignment in an expression?

Many people used to C or Perl complain that they want to use this C idiom:

```
while (line = readline(f)) {
    // do something with line
}
```

where in Python you’re forced to write this:

```
while True:
    line = f.readline()
    if not line:
        break
    ... # do something with line
```

The reason for not allowing assignment in Python expressions is a common, hard-to-find bug in those other languages, caused by this construct:

```
if (x = 0) {
    // error handling
}
else {
    // code that only works for nonzero x
}
```

The error is a simple typo: `x = 0`, which assigns 0 to the variable `x`, was written while the comparison `x == 0` is certainly what was intended.

Many alternatives have been proposed. Most are hacks that save some typing but use arbitrary or cryptic syntax or keywords, and fail the simple criterion for language change proposals: it should intuitively suggest the proper meaning to a human reader who has not yet been introduced to the construct.

An interesting phenomenon is that most experienced Python programmers recognize the `while True` idiom and don’t seem to be missing the assignment in expression construct much; it’s only newcomers who express a strong desire to add this to the language.

There's an alternative way of spelling this that seems attractive but is generally less robust than the "while True" solution:

```
line = f.readline()
while line:
    ... # do something with line...
    line = f.readline()
```

The problem with this is that if you change your mind about exactly how you get the next line (e.g. you want to change it into `sys.stdin.readline()`) you have to remember to change two places in your program – the second occurrence is hidden at the bottom of the loop.

The best approach is to use iterators, making it possible to loop through objects using the `for` statement. For example, in the current version of Python file objects support the iterator protocol, so you can now write simply:

```
for line in f:
    ... # do something with line...
```

### 3.7 Why does Python use methods for some functionality (e.g. `list.index()`) but functions for other (e.g. `len(list)`)?

The major reason is history. Functions were used for those operations that were generic for a group of types and which were intended to work even for objects that didn't have methods at all (e.g. tuples). It is also convenient to have a function that can readily be applied to an amorphous collection of objects when you use the functional features of Python (`map()`, `apply()` et al).

In fact, implementing `len()`, `max()`, `min()` as a built-in function is actually less code than implementing them as methods for each type. One can quibble about individual cases but it's a part of Python, and it's too late to make such fundamental changes now. The functions have to remain to avoid massive code breakage.

---

**Note:** For string operations, Python has moved from external functions (the `string` module) to methods. However, `len()` is still a function.

---

### 3.8 Why is `join()` a string method instead of a list or tuple method?

Strings became much more like other standard types starting in Python 1.6, when methods were added which give the same functionality that has always been available using the functions of the `string` module. Most of these new methods have been widely accepted, but the one which appears to make some programmers feel uncomfortable is:

```
", ".join(['1', '2', '4', '8', '16'])
```

which gives the result:

```
"1, 2, 4, 8, 16"
```

There are two common arguments against this usage.

The first runs along the lines of: "It looks really ugly using a method of a string literal (string constant)", to which the answer is that it might, but a string literal is just a fixed value. If the methods are to be allowed on names bound to strings there is no logical reason to make them unavailable on literals.

The second objection is typically cast as: "I am really telling a sequence to join its members together with a string constant". Sadly, you aren't. For some reason there seems to be much less difficulty with having `split()` as a string method, since in that case it is easy to see that

```
"1, 2, 4, 8, 16".split(", ")
```

is an instruction to a string literal to return the substrings delimited by the given separator (or, by default, arbitrary runs of white space). In this case a Unicode string returns a list of Unicode strings, an ASCII string returns a list of ASCII strings, and everyone is happy.

`join()` is a string method because in using it you are telling the separator string to iterate over a sequence of strings and insert itself between adjacent elements. This method can be used with any argument which obeys the rules for sequence objects, including any new classes you might define yourself.

Because this is a string method it can work for Unicode strings as well as plain ASCII strings. If `join()` were a method of the sequence types then the sequence types would have to decide which type of string to return depending on the type of the separator.

If none of these arguments persuade you, then for the moment you can continue to use the `join()` function from the `string` module, which allows you to write

```
string.join(['1', '2', '4', '8', '16'], ", ")
```

### 3.9 How fast are exceptions?

A `try/except` block is extremely efficient if no exceptions are raised. Actually catching an exception is expensive. In versions of Python prior to 2.0 it was common to use this idiom:

```
try:
    value = mydict[key]
except KeyError:
    mydict[key] = getvalue(key)
    value = mydict[key]
```

This only made sense when you expected the dict to have the key almost all the time. If that wasn't the case, you coded it like this:

```
if key in mydict:
    value = mydict[key]
else:
    value = mydict[key] = getvalue(key)
```

---

**Note:** In Python 2.0 and higher, you can code this as `value = mydict.setdefault(key, getvalue(key))`.

---

### 3.10 Why isn't there a switch or case statement in Python?

You can do this easily enough with a sequence of `if... elif... elif... else`. There have been some proposals for switch statement syntax, but there is no consensus (yet) on whether and how to do range tests. See [PEP 275](#) for complete details and the current status.

For cases where you need to choose from a very large number of possibilities, you can create a dictionary mapping case values to functions to call. For example:

```
def function_1(...):
    ...

functions = {'a': function_1,
```

```
'b': function_2,  
'c': self.method_1, ...}
```

```
func = functions[value]  
func()
```

For calling methods on objects, you can simplify yet further by using the `getattr()` built-in to retrieve methods with a particular name:

```
def visit_a(self, ...):  
    ...  
    ...  
  
def dispatch(self, value):  
    method_name = 'visit_' + str(value)  
    method = getattr(self, method_name)  
    method()
```

It's suggested that you use a prefix for the method names, such as `visit_` in this example. Without such a prefix, if values are coming from an untrusted source, an attacker would be able to call any method on your object.

### 3.11 Can't you emulate threads in the interpreter instead of relying on an OS-specific thread implementation?

Answer 1: Unfortunately, the interpreter pushes at least one C stack frame for each Python stack frame. Also, extensions can call back into Python at almost random moments. Therefore, a complete threads implementation requires thread support for C.

Answer 2: Fortunately, there is [Stackless Python](#), which has a completely redesigned interpreter loop that avoids the C stack. It's still experimental but looks very promising. Although it is binary compatible with standard Python, it's still unclear whether Stackless will make it into the core – maybe it's just too revolutionary.

### 3.12 Why can't lambda forms contain statements?

Python lambda forms cannot contain statements because Python's syntactic framework can't handle statements nested inside expressions. However, in Python, this is not a serious problem. Unlike lambda forms in other languages, where they add functionality, Python lambdas are only a shorthand notation if you're too lazy to define a function.

Functions are already first class objects in Python, and can be declared in a local scope. Therefore the only advantage of using a lambda form instead of a locally-defined function is that you don't need to invent a name for the function – but that's just a local variable to which the function object (which is exactly the same type of object that a lambda form yields) is assigned!

### 3.13 Can Python be compiled to machine code, C or some other language?

Not easily. Python's high level data types, dynamic typing of objects and run-time invocation of the interpreter (using `eval()` or `exec`) together mean that a "compiled" Python program would probably consist mostly of calls into the Python run-time system, even for seemingly simple operations like `x+1`.

Several projects described in the Python newsgroup or at past [Python conferences](#) have shown that this approach is feasible, although the speedups reached so far are only modest (e.g. 2x). Jython uses the same strategy for compiling to Java bytecode. (Jim Hugunin has demonstrated that in combination with whole-program analysis, speedups of 1000x are feasible for small demo programs. See the proceedings from the [1997 Python conference](#) for more information.)

Internally, Python source code is always translated into a bytecode representation, and this bytecode is then executed by the Python virtual machine. In order to avoid the overhead of repeatedly parsing and translating modules that rarely change, this byte code is written into a file whose name ends in ".pyc" whenever a module is parsed. When the corresponding .py file is changed, it is parsed and translated again and the .pyc file is rewritten.

There is no performance difference once the .pyc file has been loaded, as the bytecode read from the .pyc file is exactly the same as the bytecode created by direct translation. The only difference is that loading code from a .pyc file is faster than parsing and translating a .py file, so the presence of precompiled .pyc files improves the start-up time of Python scripts. If desired, the Lib/compileall.py module can be used to create valid .pyc files for a given set of modules.

Note that the main script executed by Python, even if its filename ends in .py, is not compiled to a .pyc file. It is compiled to bytecode, but the bytecode is not saved to a file. Usually main scripts are quite short, so this doesn't cost much speed.

There are also several programs which make it easier to intermingle Python and C code in various ways to increase performance. See, for example, [Psyco](#), [Pyrex](#), [PyInline](#), [Py2Cmod](#), and [Weave](#).

## 3.14 How does Python manage memory?

The details of Python memory management depend on the implementation. The standard C implementation of Python uses reference counting to detect inaccessible objects, and another mechanism to collect reference cycles, periodically executing a cycle detection algorithm which looks for inaccessible cycles and deletes the objects involved. The gc module provides functions to perform a garbage collection, obtain debugging statistics, and tune the collector's parameters.

Jython relies on the Java runtime so the JVM's garbage collector is used. This difference can cause some subtle porting problems if your Python code depends on the behavior of the reference counting implementation.

Sometimes objects get stuck in tracebacks temporarily and hence are not deallocated when you might expect. Clear the tracebacks with:

```
import sys
sys.exc_clear()
sys.exc_traceback = sys.last_traceback = None
```

Tracebacks are used for reporting errors, implementing debuggers and related things. They contain a portion of the program state extracted during the handling of an exception (usually the most recent exception).

In the absence of circularities and tracebacks, Python programs do not need to manage memory explicitly.

Why doesn't Python use a more traditional garbage collection scheme? For one thing, this is not a C standard feature and hence it's not portable. (Yes, we know about the Boehm GC library. It has bits of assembler code for *most* common platforms, not for all of them, and although it is mostly transparent, it isn't completely transparent; patches are required to get Python to work with it.)

Traditional GC also becomes a problem when Python is embedded into other applications. While in a standalone Python it's fine to replace the standard malloc() and free() with versions provided by the GC library, an application embedding Python may want to have its *own* substitute for malloc() and free(), and may not want Python's. Right now, Python works with anything that implements malloc() and free() properly.

In Jython, the following code (which is fine in CPython) will probably run out of file descriptors long before it runs out of memory:

```
for file in very_long_list_of_files:
    f = open(file)
    c = f.read(1)
```

Using the current reference counting and destructor scheme, each new assignment to `f` closes the previous file. Using GC, this is not guaranteed. If you want to write code that will work with any Python implementation, you should explicitly close the file or use the `with` statement; this will work regardless of GC:

```
for file in very_long_list_of_files:
    with open(file) as f:
        c = f.read(1)
```

### 3.15 Why isn't all memory freed when Python exits?

Objects referenced from the global namespaces of Python modules are not always deallocated when Python exits. This may happen if there are circular references. There are also certain bits of memory that are allocated by the C library that are impossible to free (e.g. a tool like Purify will complain about these). Python is, however, aggressive about cleaning up memory on exit and does try to destroy every single object.

If you want to force Python to delete certain things on deallocation use the `atexit` module to run a function that will force those deletions.

### 3.16 Why are there separate tuple and list data types?

Lists and tuples, while similar in many respects, are generally used in fundamentally different ways. Tuples can be thought of as being similar to Pascal records or C structs; they're small collections of related data which may be of different types which are operated on as a group. For example, a Cartesian coordinate is appropriately represented as a tuple of two or three numbers.

Lists, on the other hand, are more like arrays in other languages. They tend to hold a varying number of objects all of which have the same type and which are operated on one-by-one. For example, `os.listdir('.')` returns a list of strings representing the files in the current directory. Functions which operate on this output would generally not break if you added another file or two to the directory.

Tuples are immutable, meaning that once a tuple has been created, you can't replace any of its elements with a new value. Lists are mutable, meaning that you can always change a list's elements. Only immutable elements can be used as dictionary keys, and hence only tuples and not lists can be used as keys.

### 3.17 How are lists implemented?

Python's lists are really variable-length arrays, not Lisp-style linked lists. The implementation uses a contiguous array of references to other objects, and keeps a pointer to this array and the array's length in a list head structure.

This makes indexing a list `a[i]` an operation whose cost is independent of the size of the list or the value of the index.

When items are appended or inserted, the array of references is resized. Some cleverness is applied to improve the performance of appending items repeatedly; when the array must be grown, some extra space is allocated so the next few times don't require an actual resize.

## 3.18 How are dictionaries implemented?

Python’s dictionaries are implemented as resizable hash tables. Compared to B-trees, this gives better performance for lookup (the most common operation by far) under most circumstances, and the implementation is simpler.

Dictionaries work by computing a hash code for each key stored in the dictionary using the `hash()` built-in function. The hash code varies widely depending on the key; for example, “Python” hashes to -539294296 while “python”, a string that differs by a single bit, hashes to 1142331976. The hash code is then used to calculate a location in an internal array where the value will be stored. Assuming that you’re storing keys that all have different hash values, this means that dictionaries take constant time –  $O(1)$ , in computer science notation – to retrieve a key. It also means that no sorted order of the keys is maintained, and traversing the array as the `.keys()` and `.items()` do will output the dictionary’s content in some arbitrary jumbled order.

## 3.19 Why must dictionary keys be immutable?

The hash table implementation of dictionaries uses a hash value calculated from the key value to find the key. If the key were a mutable object, its value could change, and thus its hash could also change. But since whoever changes the key object can’t tell that it was being used as a dictionary key, it can’t move the entry around in the dictionary. Then, when you try to look up the same object in the dictionary it won’t be found because its hash value is different. If you tried to look up the old value it wouldn’t be found either, because the value of the object found in that hash bin would be different.

If you want a dictionary indexed with a list, simply convert the list to a tuple first; the function `tuple(L)` creates a tuple with the same entries as the list `L`. Tuples are immutable and can therefore be used as dictionary keys.

Some unacceptable solutions that have been proposed:

- Hash lists by their address (object ID). This doesn’t work because if you construct a new list with the same value it won’t be found; e.g.:

```
mydict = {[1, 2]: '12'}
print mydict[[1, 2]]
```

would raise a `KeyError` exception because the id of the `[1, 2]` used in the second line differs from that in the first line. In other words, dictionary keys should be compared using `==`, not using `is`.

- Make a copy when using a list as a key. This doesn’t work because the list, being a mutable object, could contain a reference to itself, and then the copying code would run into an infinite loop.
- Allow lists as keys but tell the user not to modify them. This would allow a class of hard-to-track bugs in programs when you forgot or modified a list by accident. It also invalidates an important invariant of dictionaries: every value in `d.keys()` is usable as a key of the dictionary.
- Mark lists as read-only once they are used as a dictionary key. The problem is that it’s not just the top-level object that could change its value; you could use a tuple containing a list as a key. Entering anything as a key into a dictionary would require marking all objects reachable from there as read-only – and again, self-referential objects could cause an infinite loop.

There is a trick to get around this if you need to, but use it at your own risk: You can wrap a mutable structure inside a class instance which has both a `__eq__()` and a `__hash__()` method. You must then make sure that the hash value for all such wrapper objects that reside in a dictionary (or other hash based structure), remain fixed while the object is in the dictionary (or other structure).

```
class ListWrapper:
    def __init__(self, the_list):
        self.the_list = the_list
    def __eq__(self, other):
```

```
    return self.the_list == other.the_list
def __hash__(self):
    l = self.the_list
    result = 98767 - len(l)*555
    for i, el in enumerate(l):
        try:
            result = result + (hash(el) % 9999999) * 1001 + i
        except Exception:
            result = (result % 7777777) + i * 333
    return result
```

Note that the hash computation is complicated by the possibility that some members of the list may be unhashable and also by the possibility of arithmetic overflow.

Furthermore it must always be the case that if `o1 == o2` (ie `o1.__eq__(o2)` is True) then `hash(o1) == hash(o2)` (ie, `o1.__hash__() == o2.__hash__()`), regardless of whether the object is in a dictionary or not. If you fail to meet these restrictions dictionaries and other hash based structures will misbehave.

In the case of `ListWrapper`, whenever the wrapper object is in a dictionary the wrapped list must not change to avoid anomalies. Don't do this unless you are prepared to think hard about the requirements and the consequences of not meeting them correctly. Consider yourself warned.

### 3.20 Why doesn't `list.sort()` return the sorted list?

In situations where performance matters, making a copy of the list just to sort it would be wasteful. Therefore, `list.sort()` sorts the list in place. In order to remind you of that fact, it does not return the sorted list. This way, you won't be fooled into accidentally overwriting a list when you need a sorted copy but also need to keep the unsorted version around.

In Python 2.4 a new built-in function – `sorted()` – has been added. This function creates a new list from a provided iterable, sorts it and returns it. For example, here's how to iterate over the keys of a dictionary in sorted order:

```
for key in sorted(mydict):
    ... # do whatever with mydict[key]...
```

### 3.21 How do you specify and enforce an interface spec in Python?

An interface specification for a module as provided by languages such as C++ and Java describes the prototypes for the methods and functions of the module. Many feel that compile-time enforcement of interface specifications helps in the construction of large programs.

Python 2.6 adds an `abc` module that lets you define Abstract Base Classes (ABCs). You can then use `isinstance()` and `issubclass()` to check whether an instance or a class implements a particular ABC. The `collections` module defines a set of useful ABCs such as `Iterable`, `Container`, and `MutableMapping`.

For Python, many of the advantages of interface specifications can be obtained by an appropriate test discipline for components. There is also a tool, `PyChecker`, which can be used to find problems due to subclassing.

A good test suite for a module can both provide a regression test and serve as a module interface specification and a set of examples. Many Python modules can be run as a script to provide a simple “self test.” Even modules which use complex external interfaces can often be tested in isolation using trivial “stub” emulations of the external interface. The `doctest` and `unittest` modules or third-party test frameworks can be used to construct exhaustive test suites that exercise every line of code in a module.

An appropriate testing discipline can help build large complex applications in Python as well as having interface specifications would. In fact, it can be better because an interface specification cannot test certain properties of a program. For example, the `append()` method is expected to add new elements to the end of some internal list; an interface specification cannot test that your `append()` implementation will actually do this correctly, but it's trivial to check this property in a test suite.

Writing test suites is very helpful, and you might want to design your code with an eye to making it easily tested. One increasingly popular technique, test-directed development, calls for writing parts of the test suite first, before you write any of the actual code. Of course Python allows you to be sloppy and not write test cases at all.

## 3.22 Why are default values shared between objects?

This type of bug commonly bites neophyte programmers. Consider this function:

```
def foo(mydict={}): # Danger: shared reference to one dict for all calls
    ... compute something ...
    mydict[key] = value
    return mydict
```

The first time you call this function, `mydict` contains a single item. The second time, `mydict` contains two items because when `foo()` begins executing, `mydict` starts out with an item already in it.

It is often expected that a function call creates new objects for default values. This is not what happens. Default values are created exactly once, when the function is defined. If that object is changed, like the dictionary in this example, subsequent calls to the function will refer to this changed object.

By definition, immutable objects such as numbers, strings, tuples, and `None`, are safe from change. Changes to mutable objects such as dictionaries, lists, and class instances can lead to confusion.

Because of this feature, it is good programming practice to not use mutable objects as default values. Instead, use `None` as the default value and inside the function, check if the parameter is `None` and create a new list/dictionary/whatever if it is. For example, don't write:

```
def foo(mydict={}):
    ...
```

but:

```
def foo(mydict=None):
    if mydict is None:
        mydict = {} # create a new dict for local namespace
```

This feature can be useful. When you have a function that's time-consuming to compute, a common technique is to cache the parameters and the resulting value of each call to the function, and return the cached value if the same value is requested again. This is called "memoizing", and can be implemented like this:

```
# Callers will never provide a third parameter for this function.
def expensive (arg1, arg2, _cache={}):
    if (arg1, arg2) in _cache:
        return _cache[(arg1, arg2)]

    # Calculate the value
    result = ... expensive computation ...
    _cache[(arg1, arg2)] = result # Store result in the cache
    return result
```

You could use a global variable containing a dictionary instead of the default value; it's a matter of taste.

### 3.23 Why is there no goto?

You can use exceptions to provide a “structured goto” that even works across function calls. Many feel that exceptions can conveniently emulate all reasonable uses of the “go” or “goto” constructs of C, Fortran, and other languages. For example:

```
class label: pass # declare a label

try:
    ...
    if (condition): raise label() # goto label
    ...
except label: # where to goto
    pass
...
```

This doesn't allow you to jump into the middle of a loop, but that's usually considered an abuse of goto anyway. Use sparingly.

### 3.24 Why can't raw strings (r-strings) end with a backslash?

More precisely, they can't end with an odd number of backslashes: the unpaired backslash at the end escapes the closing quote character, leaving an unterminated string.

Raw strings were designed to ease creating input for processors (chiefly regular expression engines) that want to do their own backslash escape processing. Such processors consider an unmatched trailing backslash to be an error anyway, so raw strings disallow that. In return, they allow you to pass on the string quote character by escaping it with a backslash. These rules work well when r-strings are used for their intended purpose.

If you're trying to build Windows pathnames, note that all Windows system calls accept forward slashes too:

```
f = open("/mydir/file.txt") # works fine!
```

If you're trying to build a pathname for a DOS command, try e.g. one of

```
dir = r"\this\is\my\dos\dir" "\\\"
dir = r"\this\is\my\dos\dir\" "[:-1]
dir = "\\this\\is\\my\\dos\\dir\\"
```

### 3.25 Why doesn't Python have a “with” statement for attribute assignments?

Python has a ‘with’ statement that wraps the execution of a block, calling code on the entrance and exit from the block. Some language have a construct that looks like this:

```
with obj:
    a = 1 # equivalent to obj.a = 1
    total = total + 1 # obj.total = obj.total + 1
```

In Python, such a construct would be ambiguous.

Other languages, such as Object Pascal, Delphi, and C++, use static types, so it's possible to know, in an unambiguous way, what member is being assigned to. This is the main point of static typing – the compiler *always* knows the scope of every variable at compile time.

Python uses dynamic types. It is impossible to know in advance which attribute will be referenced at runtime. Member attributes may be added or removed from objects on the fly. This makes it impossible to know, from a simple reading, what attribute is being referenced: a local one, a global one, or a member attribute?

For instance, take the following incomplete snippet:

```
def foo(a):
    with a:
        print x
```

The snippet assumes that “a” must have a member attribute called “x”. However, there is nothing in Python that tells the interpreter this. What should happen if “a” is, let us say, an integer? If there is a global variable named “x”, will it be used inside the with block? As you see, the dynamic nature of Python makes such choices much harder.

The primary benefit of “with” and similar language features (reduction of code volume) can, however, easily be achieved in Python by assignment. Instead of:

```
function(args).mydict[index][index].a = 21
function(args).mydict[index][index].b = 42
function(args).mydict[index][index].c = 63
```

write this:

```
ref = function(args).mydict[index][index]
ref.a = 21
ref.b = 42
ref.c = 63
```

This also has the side-effect of increasing execution speed because name bindings are resolved at run-time in Python, and the second version only needs to perform the resolution once.

## 3.26 Why are colons required for the if/while/def/class statements?

The colon is required primarily to enhance readability (one of the results of the experimental ABC language). Consider this:

```
if a == b
    print a
```

versus

```
if a == b:
    print a
```

Notice how the second one is slightly easier to read. Notice further how a colon sets off the example in this FAQ answer; it’s a standard usage in English.

Another minor reason is that the colon makes it easier for editors with syntax highlighting; they can look for colons to decide when indentation needs to be increased instead of having to do a more elaborate parsing of the program text.

## 3.27 Why does Python allow commas at the end of lists and tuples?

Python lets you add a trailing comma at the end of lists, tuples, and dictionaries:

```
[1, 2, 3,]
('a', 'b', 'c',)
d = {
    "A": [1, 5],
```

```
    "B": [6, 7], # last trailing comma is optional but good style
}
```

There are several reasons to allow this.

When you have a literal value for a list, tuple, or dictionary spread across multiple lines, it's easier to add more elements because you don't have to remember to add a comma to the previous line. The lines can also be sorted in your editor without creating a syntax error.

Accidentally omitting the comma can lead to errors that are hard to diagnose. For example:

```
x = [
    "fee",
    "fie"
    "foo",
    "fum"
]
```

This list looks like it has four elements, but it actually contains three: “fee”, “fiefoo” and “fum”. Always adding the comma avoids this source of error.

Allowing the trailing comma may also make programmatic code generation easier.

# LIBRARY AND EXTENSION FAQ

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## 4.1 General Library Questions

### 4.1.1 How do I find a module or application to perform task X?

Check *the Library Reference* to see if there's a relevant standard library module. (Eventually you'll learn what's in the standard library and will be able to skip this step.)

For third-party packages, search the [Python Package Index](#) or try [Google](#) or another Web search engine. Searching for

“Python” plus a keyword or two for your topic of interest will usually find something helpful.

#### 4.1.2 Where is the `math.py` (`socket.py`, `regex.py`, etc.) source file?

If you can't find a source file for a module it may be a built-in or dynamically loaded module implemented in C, C++ or other compiled language. In this case you may not have the source file or it may be something like `mathmodule.c`, somewhere in a C source directory (not on the Python Path).

There are (at least) three kinds of modules in Python:

1. modules written in Python (`.py`);
2. modules written in C and dynamically loaded (`.dll`, `.pyd`, `.so`, `.sl`, etc);
3. modules written in C and linked with the interpreter; to get a list of these, type:

```
import sys
print sys.builtin_module_names
```

#### 4.1.3 How do I make a Python script executable on Unix?

You need to do two things: the script file's mode must be executable and the first line must begin with `#!` followed by the path of the Python interpreter.

The first is done by executing `chmod +x scriptfile` or perhaps `chmod 755 scriptfile`.

The second can be done in a number of ways. The most straightforward way is to write

```
#!/usr/local/bin/python
```

as the very first line of your file, using the pathname for where the Python interpreter is installed on your platform.

If you would like the script to be independent of where the Python interpreter lives, you can use the `env` program. Almost all Unix variants support the following, assuming the Python interpreter is in a directory on the user's

`PATH`:

```
#!/usr/bin/env python
```

*Don't* do this for CGI scripts. The `PATH` variable for CGI scripts is often very minimal, so you need to use the actual absolute pathname of the interpreter.

Occasionally, a user's environment is so full that the `/usr/bin/env` program fails; or there's no `env` program at all. In that case, you can try the following hack (due to Alex Rezinsky):

```
#!/bin/sh
""":
exec python $0 ${1+"$@"}
"""
```

The minor disadvantage is that this defines the script's `__doc__` string. However, you can fix that by adding

```
__doc__ = """...Whatever..."""
```

#### 4.1.4 Is there a `curses/termcap` package for Python?

For Unix variants the standard Python source distribution comes with a `curses` module in the `Modules` subdirectory, though it's not compiled by default. (Note that this is not available in the Windows distribution – there is no `curses` module for Windows.)

The `curses` module supports basic curses features as well as many additional functions from `ncurses` and `SVSVCurses` such as colour, alternative character set support, pads, and mouse support. This means the module isn't compatible with operating systems that only have BSD curses, but there don't seem to be any currently maintained OSes that fall into this category.

For Windows: use the `consolelib` module.

### 4.1.5 Is there an equivalent to C's `onexit()` in Python?

The `atexit` module provides a register function that is similar to C's `onexit()`.

### 4.1.6 Why don't my signal handlers work?

The most common problem is that the signal handler is declared with the wrong argument list. It is called as `handler(signum, frame)`

so it should be declared with two arguments:

```
def handler(signum, frame):  
    ...
```

## 4.2 Common tasks

### 4.2.1 How do I test a Python program or component?

Python comes with two testing frameworks. The `doctest` module finds examples in the docstrings for a module and runs them, comparing the output with the expected output given in the docstring.

The `unittest` module is a fancier testing framework modelled on Java and Smalltalk testing frameworks.

To make testing easier, you should use good modular design in your program. Your program should have almost all functionality encapsulated in either functions or class methods – and this sometimes has the surprising and delightful effect of making the program run faster (because local variable accesses are faster than global accesses). Furthermore the program should avoid depending on mutating global variables, since this makes testing much more difficult to do.

The “global main logic” of your program may be as simple as

```
if __name__ == "__main__":  
    main_logic()
```

at the bottom of the main module of your program.

Once your program is organized as a tractable collection of functions and class behaviours you should write test functions that exercise the behaviours. A test suite that automates a sequence of tests can be associated with each module. This sounds like a lot of work, but since Python is so terse and flexible it's surprisingly easy. You can make coding much more pleasant and fun by writing your test functions in parallel with the “production code”, since this makes it easy to find bugs and even design flaws earlier.

“Support modules” that are not intended to be the main module of a program may include a self-test of the module.

```
if __name__ == "__main__":  
    self_test()
```

Even programs that interact with complex external interfaces may be tested when the external interfaces are unavailable by using “fake” interfaces implemented in Python.

## 4.2.2 How do I create documentation from doc strings?

The `pydoc` module can create HTML from the doc strings in your Python source code. An alternative for creating API documentation purely from docstrings is `epydoc`. `Sphinx` can also include docstring content.

## 4.2.3 How do I get a single keypress at a time?

For Unix variants there are several solutions. It's straightforward to do this using `curses`, but `curses` is a fairly large module to learn. Here's a solution without `curses`:

```
import termios, fcntl, sys, os
fd = sys.stdin.fileno()

oldterm = termios.tcgetattr(fd)
newattr = termios.tcgetattr(fd)
newattr[3] = newattr[3] & ~termios.ICANON & ~termios.ECHO
termios.tcsetattr(fd, termios.TCSANOW, newattr)

oldflags = fcntl.fcntl(fd, fcntl.F_GETFL)
fcntl.fcntl(fd, fcntl.F_SETFL, oldflags | os.O_NONBLOCK)

try:
    while 1:
        try:
            c = sys.stdin.read(1)
            print "Got character", repr(c)
        except IOError: pass
finally:
    termios.tcsetattr(fd, termios.TCSAFLUSH, oldterm)
    fcntl.fcntl(fd, fcntl.F_SETFL, oldflags)
```

You need the `termios` and the `fcntl` module for any of this to work, and I've only tried it on Linux, though it should work elsewhere. In this code, characters are read and printed one at a time.

`termios.tcsetattr()` turns off stdin's echoing and disables canonical mode. `fcntl.fcntl()` is used to obtain stdin's file descriptor flags and modify them for non-blocking mode. Since reading stdin when it is empty results in an `IOError`, this error is caught and ignored.

## 4.3 Threads

### 4.3.1 How do I program using threads?

Be sure to use the `threading` module and not the `thread` module. The `threading` module builds convenient abstractions on top of the low-level primitives provided by the `thread` module.

Aahz has a set of slides from his threading tutorial that are helpful; see <http://www.pythoncraft.com/OSCON2001/>.

### 4.3.2 None of my threads seem to run: why?

As soon as the main thread exits, all threads are killed. Your main thread is running too quickly, giving the threads no time to do any work.

A simple fix is to add a sleep to the end of the program that's long enough for all the threads to finish:

```
import threading, time

def thread_task(name, n):
    for i in range(n): print name, i

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(i), i))
    T.start()

time.sleep(10) # <-----!

```

But now (on many platforms) the threads don't run in parallel, but appear to run sequentially, one at a time! The reason is that the OS thread scheduler doesn't start a new thread until the previous thread is blocked.

A simple fix is to add a tiny sleep to the start of the run function:

```
def thread_task(name, n):
    time.sleep(0.001) # <-----!
    for i in range(n): print name, i

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(i), i))
    T.start()

time.sleep(10)

```

Instead of trying to guess a good delay value for `time.sleep()`, it's better to use some kind of semaphore mechanism. One idea is to use the `Queue` module to create a queue object, let each thread append a token to the queue when it finishes, and let the main thread read as many tokens from the queue as there are threads.

### 4.3.3 How do I parcel out work among a bunch of worker threads?

Use the `Queue` module to create a queue containing a list of jobs. The `Queue` class maintains a list of objects and has a `.put(obj)` method that adds items to the queue and a `.get()` method to return them. The class will take care of the locking necessary to ensure that each job is handed out exactly once.

Here's a trivial example:

```
import threading, Queue, time

# The worker thread gets jobs off the queue. When the queue is empty, it
# assumes there will be no more work and exits.
# (Realistically workers will run until terminated.)
def worker():
    print 'Running worker'
    time.sleep(0.1)
    while True:
        try:
            arg = q.get(block=False)
        except Queue.Empty:
            print 'Worker', threading.currentThread(),
            print 'queue empty'
            break
        else:
            print 'Worker', threading.currentThread(),
            print 'running with argument', arg

```

```

        time.sleep(0.5)

# Create queue
q = Queue.Queue()

# Start a pool of 5 workers
for i in range(5):
    t = threading.Thread(target=worker, name='worker %i' % (i+1))
    t.start()

# Begin adding work to the queue
for i in range(50):
    q.put(i)

# Give threads time to run
print 'Main thread sleeping'
time.sleep(5)

```

When run, this will produce the following output:

```

Running worker
Running worker
Running worker
Running worker
Running worker
Main thread sleeping
Worker <Thread(worker 1, started)> running with argument 0
Worker <Thread(worker 2, started)> running with argument 1
Worker <Thread(worker 3, started)> running with argument 2
Worker <Thread(worker 4, started)> running with argument 3
Worker <Thread(worker 5, started)> running with argument 4
Worker <Thread(worker 1, started)> running with argument 5
...

```

Consult the module's documentation for more details; the `Queue` class provides a featureful interface.

#### 4.3.4 What kinds of global value mutation are thread-safe?

A *global interpreter lock* (GIL) is used internally to ensure that only one thread runs in the Python VM at a time. In general, Python offers to switch among threads only between bytecode instructions; how frequently it switches can be set via `sys.setcheckinterval()`. Each bytecode instruction and therefore all the C implementation code reached from each instruction is therefore atomic from the point of view of a Python program.

In theory, this means an exact accounting requires an exact understanding of the PVM bytecode implementation. In practice, it means that operations on shared variables of built-in data types (ints, lists, dicts, etc) that “look atomic” really are.

For example, the following operations are all atomic (L, L1, L2 are lists, D, D1, D2 are dicts, x, y are objects, i, j are ints):

```

L.append(x)
L1.extend(L2)
x = L[i]
x = L.pop()
L1[i:j] = L2
L.sort()

```

```
x = y
x.field = y
D[x] = y
D1.update(D2)
D.keys()
```

These aren't:

```
i = i+1
L.append(L[-1])
L[i] = L[j]
D[x] = D[x] + 1
```

Operations that replace other objects may invoke those other objects' `__del__()` method when their reference count reaches zero, and that can affect things. This is especially true for the mass updates to dictionaries and lists. When in doubt, use a mutex!

### 4.3.5 Can't we get rid of the Global Interpreter Lock?

The *global interpreter lock* (GIL) is often seen as a hindrance to Python's deployment on high-end multiprocessor server machines, because a multi-threaded Python program effectively only uses one CPU, due to the insistence that (almost) all Python code can only run while the GIL is held.

Back in the days of Python 1.5, Greg Stein actually implemented a comprehensive patch set (the "free threading" patches) that removed the GIL and replaced it with fine-grained locking. Unfortunately, even on Windows (where locks are very efficient) this ran ordinary Python code about twice as slow as the interpreter using the GIL. On Linux the performance loss was even worse because pthread locks aren't as efficient.

Since then, the idea of getting rid of the GIL has occasionally come up but nobody has found a way to deal with the expected slowdown, and users who don't use threads would not be happy if their code ran at half the speed. Greg's free threading patch set has not been kept up-to-date for later Python versions.

This doesn't mean that you can't make good use of Python on multi-CPU machines! You just have to be creative with dividing the work up between multiple *processes* rather than multiple *threads*. Judicious use of C extensions will also help; if you use a C extension to perform a time-consuming task, the extension can release the GIL while the thread of execution is in the C code and allow other threads to get some work done.

It has been suggested that the GIL should be a per-interpreter-state lock rather than truly global; interpreters then wouldn't be able to share objects. Unfortunately, this isn't likely to happen either. It would be a tremendous amount of work, because many object implementations currently have global state. For example, small integers and short strings are cached; these caches would have to be moved to the interpreter state. Other object types have their own free list; these free lists would have to be moved to the interpreter state. And so on.

And I doubt that it can even be done in finite time, because the same problem exists for 3rd party extensions. It is likely that 3rd party extensions are being written at a faster rate than you can convert them to store all their global state in the interpreter state.

And finally, once you have multiple interpreters not sharing any state, what have you gained over running each interpreter in a separate process?

## 4.4 Input and Output

### 4.4.1 How do I delete a file? (And other file questions...)

Use `os.remove(filename)` or `os.unlink(filename)`; for documentation, see the `os` module. The two functions are identical; `unlink()` is simply the name of the Unix system call for this function.

To remove a directory, use `os.rmdir()`; use `os.mkdir()` to create one. `os.makedirs(path)` will create any intermediate directories in `path` that don't exist. `os.removedirs(path)` will remove intermediate directories as long as they're empty; if you want to delete an entire directory tree and its contents, use `shutil.rmtree()`.

To rename a file, use `os.rename(old_path, new_path)`.

To truncate a file, open it using `f = open(filename, "r+")`, and use `f.truncate(offset)`; offset defaults to the current seek position. There's also `os.ftruncate(fd, offset)` for files opened with `os.open()`, where `fd` is the file descriptor (a small integer).

The `shutil` module also contains a number of functions to work on files including `copyfile()`, `copytree()`, and `rmtree()`.

#### 4.4.2 How do I copy a file?

The `shutil` module contains a `copyfile()` function. Note that on MacOS 9 it doesn't copy the resource fork and Finder info.

#### 4.4.3 How do I read (or write) binary data?

To read or write complex binary data formats, it's best to use the `struct` module. It allows you to take a string containing binary data (usually numbers) and convert it to Python objects; and vice versa.

For example, the following code reads two 2-byte integers and one 4-byte integer in big-endian format from a file:

```
import struct

f = open(filename, "rb") # Open in binary mode for portability
s = f.read(8)
x, y, z = struct.unpack(">hhI", s)
```

The `>` in the format string forces big-endian data; the letter `h` reads one "short integer" (2 bytes), and `I` reads one "long integer" (4 bytes) from the string.

For data that is more regular (e.g. a homogeneous list of ints or floats), you can also use the `array` module.

#### 4.4.4 I can't seem to use `os.read()` on a pipe created with `os.popen()`; why?

`os.read()` is a low-level function which takes a file descriptor, a small integer representing the opened file. `os.popen()` creates a high-level file object, the same type returned by the built-in `open()` function. Thus, to read `n` bytes from a pipe `p` created with `os.popen()`, you need to use `p.read(n)`.

#### 4.4.5 How do I run a subprocess with pipes connected to both input and output?

Use the `popen2` module. For example:

```
import popen2
fromchild, tochild = popen2.popen2("command")
tochild.write("input\n")
tochild.flush()
output = fromchild.readline()
```

Warning: in general it is unwise to do this because you can easily cause a deadlock where your process is blocked waiting for output from the child while the child is blocked waiting for input from you. This can be caused by the parent expecting the child to output more text than it does or by data being stuck in `stdio` buffers due to lack of flushing.

The Python parent can of course explicitly flush the data it sends to the child before it reads any output, but if the child is a naive C program it may have been written to never explicitly flush its output, even if it is interactive, since flushing is normally automatic.

Note that a deadlock is also possible if you use `popen3()` to read `stdout` and `stderr`. If one of the two is too large for the internal buffer (increasing the buffer size does not help) and you `read()` the other one first, there is a deadlock, too.

Note on a bug in `popen2`: unless your program calls `wait()` or `waitpid()`, finished child processes are never removed, and eventually calls to `popen2` will fail because of a limit on the number of child processes. Calling `os.waitpid()` with the `os.WNOHANG` option can prevent this; a good place to insert such a call would be before calling `popen2` again.

In many cases, all you really need is to run some data through a command and get the result back. Unless the amount of data is very large, the easiest way to do this is to write it to a temporary file and run the command with that temporary file as input. The standard module `tempfile` exports a `mktemp()` function to generate unique temporary file names.

```
import tempfile
import os
```

```
class Popen3:
    """
    This is a deadlock-safe version of popen that returns
    an object with errorlevel, out (a string) and err (a string).
    (capturestderr may not work under windows.)
    Example: print Popen3('grep spam', '\n\nhere spam\n\n').out
    """
    def __init__(self, command, input=None, capturestderr=None):
        outfile=tempfile.mktemp()
        command="( %s ) > %s" % (command, outfile)
        if input:
            infile=tempfile.mktemp()
            open(infile, "w").write(input)
            command=command+ " <"+infile
        if capturestderr:
            errfile=tempfile.mktemp()
            command=command+ " 2>"+errfile
        self.errorlevel=os.system(command) >> 8
        self.out=open(outfile, "r").read()
        os.remove(outfile)
        if input:
            os.remove(infile)
        if capturestderr:
            self.err=open(errfile, "r").read()
            os.remove(errfile)
```

Note that many interactive programs (e.g. `vi`) don't work well with pipes substituted for standard input and output. You will have to use pseudo ttys ("ptys") instead of pipes. Or you can use a Python interface to Don Libes' "expect" library. A Python extension that interfaces to `expect` is called "expy" and available from <http://expectpy.sourceforge.net>. A pure Python solution that works like `expect` is `pexpect`.

### 4.4.6 How do I access the serial (RS232) port?

For Win32, POSIX (Linux, BSD, etc.), Jython:

<http://pyserial.sourceforge.net>

For Unix, see a Usenet post by Mitch Chapman:

<http://groups.google.com/groups?selm=34A04430.CF9@ohioee.com>

#### 4.4.7 Why doesn't closing `sys.stdout` (`stdin`, `stderr`) really close it?

Python file objects are a high-level layer of abstraction on top of C streams, which in turn are a medium-level layer of abstraction on top of (among other things) low-level C file descriptors.

For most file objects you create in Python via the built-in `file` constructor, `f.close()` marks the Python file object as being closed from Python's point of view, and also arranges to close the underlying C stream. This also happens automatically in `f`'s destructor, when `f` becomes garbage.

But `stdin`, `stdout` and `stderr` are treated specially by Python, because of the special status also given to them by C. Running `sys.stdout.close()` marks the Python-level file object as being closed, but does *not* close the associated C stream.

To close the underlying C stream for one of these three, you should first be sure that's what you really want to do (e.g., you may confuse extension modules trying to do I/O). If it is, use `os.close`:

```
os.close(0)    # close C's stdin stream
os.close(1)    # close C's stdout stream
os.close(2)    # close C's stderr stream
```

## 4.5 Network/Internet Programming

### 4.5.1 What WWW tools are there for Python?

See the chapters titled *internet* and *netdata* in the Library Reference Manual. Python has many modules that will help you build server-side and client-side web systems.

A summary of available frameworks is maintained by Paul Boddie at <http://wiki.python.org/moin/WebProgramming>. Cameron Laird maintains a useful set of pages about Python web technologies at [http://phaseit.net/claird/comp.lang.python/web\\_python](http://phaseit.net/claird/comp.lang.python/web_python).

### 4.5.2 How can I mimic CGI form submission (METHOD=POST)?

I would like to retrieve web pages that are the result of POSTing a form. Is there existing code that would let me do this easily?

Yes. Here's a simple example that uses `httplib`:

```
#!/usr/local/bin/python

import httplib, sys, time

### build the query string
qs = "First=Josephine&MI=Q&Last=Public"

### connect and send the server a path
httpobj = httplib.HTTP('www.some-server.out-there', 80)
httpobj.putrequest('POST', '/cgi-bin/some-cgi-script')
```

```
### now generate the rest of the HTTP headers...
httpobj.putheader('Accept', '*/*')
httpobj.putheader('Connection', 'Keep-Alive')
httpobj.putheader('Content-type', 'application/x-www-form-urlencoded')
httpobj.putheader('Content-length', '%d' % len(qs))
httpobj.endheaders()
httpobj.send(qs)
### find out what the server said in response...
reply, msg, hdrs = httpobj.getreply()
if reply != 200:
    sys.stdout.write(httpobj.getfile().read())
```

Note that in general for percent-encoded POST operations, query strings must be quoted using `urllib.urlencode()`. For example, to send `name=Guy Steele, Jr.:`

```
>>> import urllib
>>> urllib.urlencode({'name': 'Guy Steele, Jr.'})
'name=Guy+Steele%2C+Jr.'
```

### 4.5.3 What module should I use to help with generating HTML?

You can find a collection of useful links on the [Web Programming wiki page](#).

### 4.5.4 How do I send mail from a Python script?

Use the standard library module `smtplib`.

Here's a very simple interactive mail sender that uses it. This method will work on any host that supports an SMTP listener.

```
import sys, smtplib

fromaddr = raw_input("From: ")
toaddrs = raw_input("To: ").split(',')
print "Enter message, end with ^D:"
msg = ''
while True:
    line = sys.stdin.readline()
    if not line:
        break
    msg += line

# The actual mail send
server = smtplib.SMTP('localhost')
server.sendmail(fromaddr, toaddrs, msg)
server.quit()
```

A Unix-only alternative uses `sendmail`. The location of the `sendmail` program varies between systems; sometimes it is `/usr/lib/sendmail`, sometimes `/usr/sbin/sendmail`. The `sendmail` manual page will help you out. Here's some sample code:

```
SENDMAIL = "/usr/sbin/sendmail" # sendmail location
import os
p = os.popen("%s -t -i" % SENDMAIL, "w")
p.write("To: receiver@example.com\n")
```

```
p.write("Subject: test\n")
p.write("\n") # blank line separating headers from body
p.write("Some text\n")
p.write("some more text\n")
sts = p.close()
if sts != 0:
    print "Sendmail exit status", sts
```

#### 4.5.5 How do I avoid blocking in the connect() method of a socket?

The `select` module is commonly used to help with asynchronous I/O on sockets.

To prevent the TCP connect from blocking, you can set the socket to non-blocking mode. Then when you do the `connect()`, you will either connect immediately (unlikely) or get an exception that contains the error number as `.errno.errno.EINPROGRESS` indicates that the connection is in progress, but hasn't finished yet. Different OSes will return different values, so you're going to have to check what's returned on your system.

You can use the `connect_ex()` method to avoid creating an exception. It will just return the `errno` value. To poll, you can call `connect_ex()` again later – 0 or `errno.EISCONN` indicate that you're connected – or you can pass this socket to `select` to check if it's writable.

## 4.6 Databases

### 4.6.1 Are there any interfaces to database packages in Python?

Yes.

Python 2.3 includes the `bsddb` package which provides an interface to the BerkeleyDB library. Interfaces to disk-based hashes such as `DBM` and `GDBM` are also included with standard Python.

Support for most relational databases is available. See the [DatabaseProgramming wiki page](#) for details.

### 4.6.2 How do you implement persistent objects in Python?

The `pickle` library module solves this in a very general way (though you still can't store things like open files, sockets or windows), and the `shelve` library module uses `pickle` and `(g)dbm` to create persistent mappings containing arbitrary Python objects. For better performance, you can use the `cPickle` module.

A more awkward way of doing things is to use `pickle`'s little sister, `marshal`. The `marshal` module provides very fast ways to store noncircular basic Python types to files and strings, and back again. Although `marshal` does not do fancy things like store instances or handle shared references properly, it does run extremely fast. For example, loading a half megabyte of data may take less than a third of a second. This often beats doing something more complex and general such as using `gdbm` with `pickle/shelve`.

### 4.6.3 Why is cPickle so slow?

By default `pickle` uses a relatively old and slow format for backward compatibility. You can however specify other protocol versions that are faster:

```
largeString = 'z' * (100 * 1024)
myPickle = cPickle.dumps(largeString, protocol=1)
```

#### 4.6.4 If my program crashes with a bsddb (or anydbm) database open, it gets corrupted. How come?

Databases opened for write access with the bsddb module (and often by the anydbm module, since it will preferentially use bsddb) must explicitly be closed using the `.close()` method of the database. The underlying library caches database contents which need to be converted to on-disk form and written.

If you have initialized a new bsddb database but not written anything to it before the program crashes, you will often wind up with a zero-length file and encounter an exception the next time the file is opened.

#### 4.6.5 I tried to open Berkeley DB file, but bsddb produces bsddb.error: (22, 'Invalid argument'). Help! How can I restore my data?

Don't panic! Your data is probably intact. The most frequent cause for the error is that you tried to open an earlier Berkeley DB file with a later version of the Berkeley DB library.

Many Linux systems now have all three versions of Berkeley DB available. If you are migrating from version 1 to a newer version use `db_dump185` to dump a plain text version of the database. If you are migrating from version 2 to version 3 use `db2_dump` to create a plain text version of the database. In either case, use `db_load` to create a new native database for the latest version installed on your computer. If you have version 3 of Berkeley DB installed, you should be able to use `db2_load` to create a native version 2 database.

You should move away from Berkeley DB version 1 files because the hash file code contains known bugs that can corrupt your data.

## 4.7 Mathematics and Numerics

### 4.7.1 How do I generate random numbers in Python?

The standard module `random` implements a random number generator. Usage is simple:

```
import random
random.random()
```

This returns a random floating point number in the range `[0, 1)`.

There are also many other specialized generators in this module, such as:

- `randrange(a, b)` chooses an integer in the range `[a, b)`.
- `uniform(a, b)` chooses a floating point number in the range `[a, b)`.
- `normalvariate(mean, sdev)` samples the normal (Gaussian) distribution.

Some higher-level functions operate on sequences directly, such as:

- `choice(S)` chooses random element from a given sequence
- `shuffle(L)` shuffles a list in-place, i.e. permutes it randomly

There's also a `Random` class you can instantiate to create independent multiple random number generators.

# EXTENDING/EMBEDDING FAQ

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## 5.1 Can I create my own functions in C?

Yes, you can create built-in modules containing functions, variables, exceptions and even new types in C. This is explained in the document *extending-index*.

Most intermediate or advanced Python books will also cover this topic.

## 5.2 Can I create my own functions in C++?

Yes, using the C compatibility features found in C++. Place `extern "C" { ... }` around the Python include files and put `extern "C"` before each function that is going to be called by the Python interpreter. Global or static C++ objects with constructors are probably not a good idea.

## 5.3 Writing C is hard; are there any alternatives?

There are a number of alternatives to writing your own C extensions, depending on what you're trying to do.

If you need more speed, **Psyco** generates x86 assembly code from Python bytecode. You can use Psyco to compile the most time-critical functions in your code, and gain a significant improvement with very little effort, as long as you're running on a machine with an x86-compatible processor.

**Pyrex** is a compiler that accepts a slightly modified form of Python and generates the corresponding C code. Pyrex makes it possible to write an extension without having to learn Python's C API.

If you need to interface to some C or C++ library for which no Python extension currently exists, you can try wrapping the library's data types and functions with a tool such as **SWIG**. **SIP**, **CXX Boost**, or **Weave** are also alternatives for wrapping C++ libraries.

## 5.4 How can I execute arbitrary Python statements from C?

The highest-level function to do this is `PyRun_SimpleString()` which takes a single string argument to be executed in the context of the module `__main__` and returns 0 for success and -1 when an exception occurred (including `SyntaxError`). If you want more control, use `PyRun_String()`; see the source for `PyRun_SimpleString()` in `Python/pythonrun.c`.

## 5.5 How can I evaluate an arbitrary Python expression from C?

Call the function `PyRun_String()` from the previous question with the start symbol `Py_eval_input`; it parses an expression, evaluates it and returns its value.

## 5.6 How do I extract C values from a Python object?

That depends on the object's type. If it's a tuple, `PyTuple_Size()` returns its length and `PyTuple_GetItem()` returns the item at a specified index. Lists have similar functions, `PyListSize()` and `PyList_GetItem()`.

For strings, `PyString_Size()` returns its length and `PyString_AsString()` a pointer to its value. Note that Python strings may contain null bytes so C's `strlen()` should not be used.

To test the type of an object, first make sure it isn't `NULL`, and then use `PyString_Check()`, `PyTuple_Check()`, `PyList_Check()`, etc.

There is also a high-level API to Python objects which is provided by the so-called 'abstract' interface – read `Include/abstract.h` for further details. It allows interfacing with any kind of Python sequence using calls like `PySequence_Length()`, `PySequence_GetItem()`, etc.) as well as many other useful protocols.

## 5.7 How do I use `Py_BuildValue()` to create a tuple of arbitrary length?

You can't. Use `t = PyTuple_New(n)` instead, and fill it with objects using `PyTuple_SetItem(t, i, o)` – note that this "eats" a reference count of `o`, so you have to `Py_INCREF()` it. Lists have similar functions `PyList_New(n)` and `PyList_SetItem(l, i, o)`. Note that you *must* set all the tuple items to some value before you pass the tuple to Python code – `PyTuple_New(n)` initializes them to `NULL`, which isn't a valid Python value.

## 5.8 How do I call an object's method from C?

The `PyObject_CallMethod()` function can be used to call an arbitrary method of an object. The parameters are the object, the name of the method to call, a format string like that used with `Py_BuildValue()`, and the argument values:

```
PyObject *
PyObject_CallMethod(PyObject *object, char *method_name,
                   char *arg_format, ...);
```

This works for any object that has methods – whether built-in or user-defined. You are responsible for eventually `Py_DECREF()`ing the return value.

To call, e.g., a file object's "seek" method with arguments 10, 0 (assuming the file object pointer is "f"):

```
res = PyObject_CallMethod(f, "seek", "(ii)", 10, 0);
if (res == NULL) {
    ... an exception occurred ...
}
else {
    Py_DECREF(res);
}
```

Note that since `PyObject_CallObject()` *always* wants a tuple for the argument list, to call a function without arguments, pass "()" for the format, and to call a function with one argument, surround the argument in parentheses, e.g. "(i)".

## 5.9 How do I catch the output from `PyErr_Print()` (or anything that prints to `stdout/stderr`)?

In Python code, define an object that supports the `write()` method. Assign this object to `sys.stdout` and `sys.stderr`. Call `print_error`, or just allow the standard traceback mechanism to work. Then, the output will go wherever your `write()` method sends it.

The easiest way to do this is to use the `StringIO` class in the standard library.

Sample code and use for catching `stdout`:

```
>>> class StdoutCatcher:
...     def __init__(self):
...         self.data = ''
...     def write(self, stuff):
...         self.data = self.data + stuff
...
>>> import sys
>>> sys.stdout = StdoutCatcher()
>>> print 'foo'
>>> print 'hello world!'
>>> sys.stderr.write(sys.stdout.data)
foo
hello world!
```

## 5.10 How do I access a module written in Python from C?

You can get a pointer to the module object as follows:

```
module = PyImport_ImportModule("<modulename>");
```

If the module hasn't been imported yet (i.e. it is not yet present in `sys.modules`), this initializes the module; otherwise it simply returns the value of `sys.modules["<modulename>"]`. Note that it doesn't enter the module into any namespace – it only ensures it has been initialized and is stored in `sys.modules`.

You can then access the module's attributes (i.e. any name defined in the module) as follows:

```
attr = PyObject_GetAttrString(module, "<attrname>");
```

Calling `PyObject_SetAttrString()` to assign to variables in the module also works.

## 5.11 How do I interface to C++ objects from Python?

Depending on your requirements, there are many approaches. To do this manually, begin by reading the *“Extending and Embedding” document*. Realize that for the Python run-time system, there isn't a whole lot of difference between C and C++ – so the strategy of building a new Python type around a C structure (pointer) type will also work for C++ objects.

For C++ libraries, see *Writing C is hard; are there any alternatives?*.

## 5.12 I added a module using the Setup file and the make fails; why?

Setup must end in a newline, if there is no newline there, the build process fails. (Fixing this requires some ugly shell script hackery, and this bug is so minor that it doesn't seem worth the effort.)

## 5.13 How do I debug an extension?

When using GDB with dynamically loaded extensions, you can't set a breakpoint in your extension until your extension is loaded.

In your `.gdbinit` file (or interactively), add the command:

```
br _PyImport_LoadDynamicModule
```

Then, when you run GDB:

```
$ gdb /local/bin/python
gdb) run myscript.py
gdb) continue # repeat until your extension is loaded
gdb) finish   # so that your extension is loaded
gdb) br myfunction.c:50
gdb) continue
```

## 5.14 I want to compile a Python module on my Linux system, but some files are missing. Why?

Most packaged versions of Python don't include the `/usr/lib/python2.x/config/` directory, which contains various files required for compiling Python extensions.

For Red Hat, install the `python-devel` RPM to get the necessary files.

For Debian, run `apt-get install python-dev`.

## 5.15 What does “SystemError: \_PyImport\_FixupExtension: module yourmodule not loaded” mean?

This means that you have created an extension module named “yourmodule”, but your module init function does not initialize with that name.

Every module init function will have a line similar to:

```
module = Py_InitModule("yourmodule", yourmodule_functions);
```

If the string passed to this function is not the same name as your extension module, the `SystemError` exception will be raised.

## 5.16 How do I tell “incomplete input” from “invalid input”?

Sometimes you want to emulate the Python interactive interpreter's behavior, where it gives you a continuation prompt when the input is incomplete (e.g. you typed the start of an “if” statement or you didn't close your parentheses or triple string quotes), but it gives you a syntax error message immediately when the input is invalid.

In Python you can use the `codeop` module, which approximates the parser's behavior sufficiently. IDLE uses this, for example.

The easiest way to do it in C is to call `PyRun_InteractiveLoop()` (perhaps in a separate thread) and let the Python interpreter handle the input for you. You can also set the `PyOS_ReadlineFunctionPointer()` to point at your custom input function. See `Modules/readline.c` and `Parser/myreadline.c` for more hints.

However sometimes you have to run the embedded Python interpreter in the same thread as your rest application and you can't allow the `PyRun_InteractiveLoop()` to stop while waiting for user input. The one solution then is to call `PyParser_ParseString()` and test for `e.error` equal to `E_EOF`, which means the input is incomplete). Here's a sample code fragment, untested, inspired by code from Alex Farber:

```
#include <Python.h>
#include <node.h>
#include <errcode.h>
#include <grammar.h>
#include <parsetok.h>
#include <compile.h>

int testcomplete(char *code)
/* code should end in \n */
/* return -1 for error, 0 for incomplete, 1 for complete */
{
    node *n;
```

```
perrdetail e;

n = PyParser_ParseString(code, &_PyParser_Grammar,
                        Py_file_input, &e);

if (n == NULL) {
    if (e.error == E_EOF)
        return 0;
    return -1;
}

PyNode_Free(n);
return 1;
}
```

Another solution is trying to compile the received string with `Py_CompileString()`. If it compiles without errors, try to execute the returned code object by calling `PyEval_EvalCode()`. Otherwise save the input for later. If the compilation fails, find out if it's an error or just more input is required - by extracting the message string from the exception tuple and comparing it to the string "unexpected EOF while parsing". Here is a complete example using the GNU readline library (you may want to ignore **SIGINT** while calling `readline()`):

```
#include <stdio.h>
#include <readline.h>

#include <Python.h>
#include <object.h>
#include <compile.h>
#include <eval.h>

int main (int argc, char* argv[])
{
    int i, j, done = 0;                /* lengths of line, code */
    char ps1[] = ">>> ";
    char ps2[] = "... ";
    char *prompt = ps1;
    char *msg, *line, *code = NULL;
    PyObject *src, *glb, *loc;
    PyObject *exc, *val, *trb, *obj, *dum;

    Py_Initialize ();
    loc = PyDict_New ();
    glb = PyDict_New ();
    PyDict_SetItemString (glb, "__builtins__", PyEval_GetBuiltins ());

    while (!done)
    {
        line = readline (prompt);

        if (NULL == line)              /* CTRL-D pressed */
        {
            done = 1;
        }
        else
        {
            i = strlen (line);
```

```

if (i > 0)
    add_history (line);                                /* save non-empty lines */

if (NULL == code)                                  /* nothing in code yet */
    j = 0;
else
    j = strlen (code);

code = realloc (code, i + j + 2);
if (NULL == code)                                  /* out of memory */
    exit (1);

if (0 == j)                                        /* code was empty, so */
    code[0] = '\0';                                  /* keep strcat happy */

strncat (code, line, i);                            /* append line to code */
code[i + j] = '\n';                                  /* append '\n' to code */
code[i + j + 1] = '\0';

src = Py_CompileString (code, "<stdin>", Py_single_input);

if (NULL != src)                                    /* compiled just fine - */
{
    if (ps1 == prompt ||                             /* ">>> " or */
        '\n' == code[i + j - 1])                    /* "... " and double '\n' */
    {                                                /* so execute it */
        dum = PyEval_EvalCode ((PyCodeObject *)src, glb, loc);
        Py_XDECREF (dum);
        Py_XDECREF (src);
        free (code);
        code = NULL;
        if (PyErr_Occurred ())
            PyErr_Print ();
        prompt = ps1;
    }
}                                                    /* syntax error or E_EOF? */
else if (PyErr_ExceptionMatches (PyExc_SyntaxError))
{
    PyErr_Fetch (&exc, &val, &trb);                /* clears exception! */

    if (PyArg_ParseTuple (val, "sO", &msg, &obj) &&
        !strcmp (msg, "unexpected EOF while parsing")) /* E_EOF */
    {
        Py_XDECREF (exc);
        Py_XDECREF (val);
        Py_XDECREF (trb);
        prompt = ps2;
    }
else                                            /* some other syntax error */
{
    PyErr_Restore (exc, val, trb);
    PyErr_Print ();
    free (code);
    code = NULL;
}

```

```
        prompt = ps1;
    }
}
else                                     /* some non-syntax error */
{
    PyErr_Print ();
    free (code);
    code = NULL;
    prompt = ps1;
}

free (line);
}
}

Py_XDECREF(glb);
Py_XDECREF(loc);
Py_Finalize();
exit(0);
}
```

## 5.17 How do I find undefined g++ symbols `__builtin_new` or `__pure_virtual`?

To dynamically load g++ extension modules, you must recompile Python, relink it using g++ (change LINKCC in the Python Modules Makefile), and link your extension module using g++ (e.g., `g++ -shared -o mymodule.so mymodule.o`).

## 5.18 Can I create an object class with some methods implemented in C and others in Python (e.g. through inheritance)?

In Python 2.2, you can inherit from built-in classes such as `int`, `list`, `dict`, etc.

The Boost Python Library (BPL, <http://www.boost.org/libs/python/doc/index.html>) provides a way of doing this from C++ (i.e. you can inherit from an extension class written in C++ using the BPL).

## 5.19 When importing module X, why do I get “undefined symbol: PyUnicodeUCS2\*”?

You are using a version of Python that uses a 4-byte representation for Unicode characters, but some C extension module you are importing was compiled using a Python that uses a 2-byte representation for Unicode characters (the default).

If instead the name of the undefined symbol starts with `PyUnicodeUCS4`, the problem is the reverse: Python was built using 2-byte Unicode characters, and the extension module was compiled using a Python with 4-byte Unicode characters.

This can easily occur when using pre-built extension packages. RedHat Linux 7.x, in particular, provided a “python2” binary that is compiled with 4-byte Unicode. This only causes the link failure if the extension uses any of the

`PyUnicode_*()` functions. It is also a problem if an extension uses any of the Unicode-related format specifiers for `Py_BuildValue()` (or similar) or parameter specifications for `PyArg_ParseTuple()`.

You can check the size of the Unicode character a Python interpreter is using by checking the value of `sys.maxunicode`:

```
>>> import sys
>>> if sys.maxunicode > 65535:
...     print 'UCS4 build'
... else:
...     print 'UCS2 build'
```

The only way to solve this problem is to use extension modules compiled with a Python binary built using the same size for Unicode characters.



# PYTHON ON WINDOWS FAQ

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## 6.1 How do I run a Python program under Windows?

This is not necessarily a straightforward question. If you are already familiar with running programs from the Windows command line then everything will seem obvious; otherwise, you might need a little more guidance. There are also differences between Windows 95, 98, NT, ME, 2000 and XP which can add to the confusion.



### Python Development on XP

This series of screencasts aims to get you up and running with Python on Windows XP. The knowledge is distilled into 1.5 hours and will get you up and running with the right Python distribution, coding in your choice of IDE, and debugging and writing solid code with unit-tests.

Unless you use some sort of integrated development environment, you will end up *typing* Windows commands into what is variously referred to as a “DOS window” or “Command prompt window”. Usually you can create such a window from your Start menu; under Windows 2000 the menu selection is *Start* → *Programs* → *Accessories* → *Command Prompt*. You should be able to recognize when you have started such a window because you will see a Windows “command prompt”, which usually looks like this:

```
C:\>
```

The letter may be different, and there might be other things after it, so you might just as easily see something like:

```
D:\Steve\Projects\Python>
```

depending on how your computer has been set up and what else you have recently done with it. Once you have started such a window, you are well on the way to running Python programs.

You need to realize that your Python scripts have to be processed by another program called the Python interpreter. The interpreter reads your script, compiles it into bytecodes, and then executes the bytecodes to run your program. So, how do you arrange for the interpreter to handle your Python?

First, you need to make sure that your command window recognises the word “python” as an instruction to start the interpreter. If you have opened a command window, you should try entering the command `python` and hitting return. You should then see something like:

```
Python 2.2 (#28, Dec 21 2001, 12:21:22) [MSC 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

You have started the interpreter in “interactive mode”. That means you can enter Python statements or expressions interactively and have them executed or evaluated while you wait. This is one of Python’s strongest features. Check it by entering a few expressions of your choice and seeing the results:

```
>>> print "Hello"
Hello
>>> "Hello" * 3
HelloHelloHello
```

Many people use the interactive mode as a convenient yet highly programmable calculator. When you want to end your interactive Python session, hold the Ctrl key down while you enter a Z, then hit the “Enter” key to get back to your Windows command prompt.

You may also find that you have a Start-menu entry such as *Start* → *Programs* → *Python 2.2* → *Python (command line)* that results in you seeing the `>>>` prompt in a new window. If so, the window will disappear after you enter the Ctrl-Z character; Windows is running a single “python” command in the window, and closes it when you terminate the interpreter.

If the `python` command, instead of displaying the interpreter prompt `>>>`, gives you a message like:

'python' is not recognized as an internal or external command, operable program or batch file.



### Adding Python to DOS Path

Python is not added to the DOS path by default. This screencast will walk you through the steps to add the correct entry to the *System Path*, allowing Python to be executed from the command-line by all users.

or:

Bad command or filename

then you need to make sure that your computer knows where to find the Python interpreter. To do this you will have to modify a setting called PATH, which is a list of directories where Windows will look for programs.

You should arrange for Python's installation directory to be added to the PATH of every command window as it starts. If you installed Python fairly recently then the command

```
dir C:\py*
```

will probably tell you where it is installed; the usual location is something like C:\Python23. Otherwise you will be reduced to a search of your whole disk ... use *Tools* → *Find* or hit the *Search* button and look for "python.exe". Supposing you discover that Python is installed in the C:\Python23 directory (the default at the time of writing), you should make sure that entering the command

```
c:\Python23\python
```

starts up the interpreter as above (and don't forget you'll need a "CTRL-Z" and an "Enter" to get out of it). Once you have verified the directory, you need to add it to the start-up routines your computer goes through. For older versions of Windows the easiest way to do this is to edit the C:\AUTOEXEC.BAT file. You would want to add a line like the following to AUTOEXEC.BAT:

```
PATH C:\Python23;%PATH%
```

For Windows NT, 2000 and (I assume) XP, you will need to add a string such as

```
;C:\Python23
```

to the current setting for the PATH environment variable, which you will find in the properties window of "My Computer" under the "Advanced" tab. Note that if you have sufficient privilege you might get a choice of installing the settings either for the Current User or for System. The latter is preferred if you want everybody to be able to run Python on the machine.

If you aren't confident doing any of these manipulations yourself, ask for help! At this stage you may want to reboot your system to make absolutely sure the new setting has taken effect. You probably won't need to reboot for Windows NT, XP or 2000. You can also avoid it in earlier versions by editing the file C:\WINDOWS\COMMAND\CMDINIT.BAT instead of AUTOEXEC.BAT.

You should now be able to start a new command window, enter `python` at the C:\> (or whatever) prompt, and see the >>> prompt that indicates the Python interpreter is reading interactive commands.

Let's suppose you have a program called `pytest.py` in directory C:\Steve\Projects\Python. A session to run that program might look like this:

```
C:\> cd \Steve\Projects\Python
C:\Steve\Projects\Python> python pytest.py
```

Because you added a file name to the command to start the interpreter, when it starts up it reads the Python script in the named file, compiles it, executes it, and terminates, so you see another `C:\>` prompt. You might also have entered

```
C:\> python \Steve\Projects\Python\pytest.py
```

if you hadn't wanted to change your current directory.

Under NT, 2000 and XP you may well find that the installation process has also arranged that the command `pytest.py` (or, if the file isn't in the current directory, `C:\Steve\Projects\Python\pytest.py`) will automatically recognize the ".py" extension and run the Python interpreter on the named file. Using this feature is fine, but *some* versions of Windows have bugs which mean that this form isn't exactly equivalent to using the interpreter explicitly, so be careful.

The important things to remember are:

1. Start Python from the Start Menu, or make sure the PATH is set correctly so Windows can find the Python interpreter.

```
python
```

should give you a '>>>' prompt from the Python interpreter. Don't forget the CTRL-Z and ENTER to terminate the interpreter (and, if you started the window from the Start Menu, make the window disappear).

2. Once this works, you run programs with commands:

```
python {program-file}
```

3. When you know the commands to use you can build Windows shortcuts to run the Python interpreter on any of your scripts, naming particular working directories, and adding them to your menus. Take a look at

```
python --help
```

if your needs are complex.

4. Interactive mode (where you see the >>> prompt) is best used for checking that individual statements and expressions do what you think they will, and for developing code by experiment.

## 6.2 How do I make Python scripts executable?

On Windows 2000, the standard Python installer already associates the .py extension with a file type (Python.File) and gives that file type an open command that runs the interpreter (`D:\Program Files\Python\python.exe "%1" %*`). This is enough to make scripts executable from the command prompt as 'foo.py'. If you'd rather be able to execute the script by simple typing 'foo' with no extension you need to add .py to the PATHEXT environment variable.

On Windows NT, the steps taken by the installer as described above allow you to run a script with 'foo.py', but a longtime bug in the NT command processor prevents you from redirecting the input or output of any script executed in this way. This is often important.

The incantation for making a Python script executable under WinNT is to give the file an extension of .cmd and add the following as the first line:

```
@setlocal enableextensions & python -x %~f0 %* & goto :EOF
```

## 6.3 Why does Python sometimes take so long to start?

Usually Python starts very quickly on Windows, but occasionally there are bug reports that Python suddenly begins to take a long time to start up. This is made even more puzzling because Python will work fine on other Windows systems which appear to be configured identically.

The problem may be caused by a misconfiguration of virus checking software on the problem machine. Some virus scanners have been known to introduce startup overhead of two orders of magnitude when the scanner is configured to monitor all reads from the filesystem. Try checking the configuration of virus scanning software on your systems to ensure that they are indeed configured identically. McAfee, when configured to scan all file system read activity, is a particular offender.

## 6.4 Where is Freeze for Windows?

“Freeze” is a program that allows you to ship a Python program as a single stand-alone executable file. It is *not* a compiler; your programs don’t run any faster, but they are more easily distributable, at least to platforms with the same OS and CPU. Read the README file of the freeze program for more disclaimers.

You can use freeze on Windows, but you must download the source tree (see <http://www.python.org/download/source>). The freeze program is in the `Tools\freeze` subdirectory of the source tree.

You need the Microsoft VC++ compiler, and you probably need to build Python. The required project files are in the `PCbuild` directory.

## 6.5 Is a \*.pyd file the same as a DLL?

Yes, .pyd files are dll’s, but there are a few differences. If you have a DLL named `foo.pyd`, then it must have a function `initfoo()`. You can then write Python “import foo”, and Python will search for `foo.pyd` (as well as `foo.py`, `foo.pyc`) and if it finds it, will attempt to call `initfoo()` to initialize it. You do not link your .exe with `foo.lib`, as that would cause Windows to require the DLL to be present.

Note that the search path for `foo.pyd` is `PYTHONPATH`, not the same as the path that Windows uses to search for `foo.dll`. Also, `foo.pyd` need not be present to run your program, whereas if you linked your program with a dll, the dll is required. Of course, `foo.pyd` is required if you want to say `import foo`. In a DLL, linkage is declared in the source code with `__declspec(dllexport)`. In a .pyd, linkage is defined in a list of available functions.

## 6.6 How can I embed Python into a Windows application?

Embedding the Python interpreter in a Windows app can be summarized as follows:

1. Do `_not_` build Python into your .exe file directly. On Windows, Python must be a DLL to handle importing modules that are themselves DLL’s. (This is the first key undocumented fact.) Instead, link to `pythonNN.dll`; it is typically installed in `C:\Windows\System`. `NN` is the Python version, a number such as “23” for Python 2.3.

You can link to Python in two different ways. Load-time linking means linking against `pythonNN.lib`, while run-time linking means linking against `pythonNN.dll`. (General note: `pythonNN.lib` is the so-called “import lib” corresponding to `pythonNN.dll`. It merely defines symbols for the linker.)

Run-time linking greatly simplifies link options; everything happens at run time. Your code must load `pythonNN.dll` using the Windows `LoadLibraryEx()` routine. The code must also use access routines and data in `pythonNN.dll` (that is, Python’s C API’s) using pointers obtained by the Windows

GetProcAddress() routine. Macros can make using these pointers transparent to any C code that calls routines in Python's C API.

Borland note: convert pythonNN.lib to OMF format using Coff2Omf.exe first.

2. If you use SWIG, it is easy to create a Python "extension module" that will make the app's data and methods available to Python. SWIG will handle just about all the grungy details for you. The result is C code that you link *into* your .exe file (!) You do *not* have to create a DLL file, and this also simplifies linking.
3. SWIG will create an init function (a C function) whose name depends on the name of the extension module. For example, if the name of the module is leo, the init function will be called initleo(). If you use SWIG shadow classes, as you should, the init function will be called initleoc(). This initializes a mostly hidden helper class used by the shadow class.

The reason you can link the C code in step 2 into your .exe file is that calling the initialization function is equivalent to importing the module into Python! (This is the second key undocumented fact.)

4. In short, you can use the following code to initialize the Python interpreter with your extension module.

```
#include "python.h"
...
Py_Initialize(); // Initialize Python.
initmyAppc(); // Initialize (import) the helper class.
PyRun_SimpleString("import myApp") ; // Import the shadow class.
```

5. There are two problems with Python's C API which will become apparent if you use a compiler other than MSVC, the compiler used to build pythonNN.dll.

Problem 1: The so-called "Very High Level" functions that take FILE \* arguments will not work in a multi-compiler environment because each compiler's notion of a struct FILE will be different. From an implementation standpoint these are very *\_low\_* level functions.

Problem 2: SWIG generates the following code when generating wrappers to void functions:

```
Py_INCREF(Py_None);
_resultobj = Py_None;
return _resultobj;
```

Alas, Py\_None is a macro that expands to a reference to a complex data structure called *\_Py\_NoneStruct* inside pythonNN.dll. Again, this code will fail in a multi-compiler environment. Replace such code by:

```
return Py_BuildValue("");
```

It may be possible to use SWIG's %typemap command to make the change automatically, though I have not been able to get this to work (I'm a complete SWIG newbie).

6. Using a Python shell script to put up a Python interpreter window from inside your Windows app is not a good idea; the resulting window will be independent of your app's windowing system. Rather, you (or the wxPythonWindow class) should create a "native" interpreter window. It is easy to connect that window to the Python interpreter. You can redirect Python's i/o to *\_any\_* object that supports read and write, so all you need is a Python object (defined in your extension module) that contains read() and write() methods.

## 6.7 How do I use Python for CGI?

On the Microsoft IIS server or on the Win95 MS Personal Web Server you set up Python in the same way that you would set up any other scripting engine.

Run regedt32 and go to:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\W3SVC\Parameters\ScriptMap
```

and enter the following line (making any specific changes that your system may need):

```
.py :REG_SZ: c:\<path to python>\python.exe -u %s %s
```

This line will allow you to call your script with a simple reference like: `http://yourserver/scripts/yourscript.py` provided “scripts” is an “executable” directory for your server (which it usually is by default). The `-u` flag specifies unbuffered and binary mode for stdin - needed when working with binary data.

In addition, it is recommended that using “.py” may not be a good idea for the file extensions when used in this context (you might want to reserve \*.py for support modules and use \*.cgi or \*.cgp for “main program” scripts).

In order to set up Internet Information Services 5 to use Python for CGI processing, please see the following links:

[http://www.e-coli.net/pyiis\\_server.html](http://www.e-coli.net/pyiis_server.html) (for Win2k Server) <http://www.e-coli.net/pyiis.html> (for Win2k pro)

Configuring Apache is much simpler. In the Apache configuration file `httpd.conf`, add the following line at the end of the file:

```
ScriptInterpreterSource Registry
```

Then, give your Python CGI-scripts the extension .py and put them in the cgi-bin directory.

## 6.8 How do I keep editors from inserting tabs into my Python source?

The FAQ does not recommend using tabs, and the Python style guide, [PEP 8](#), recommends 4 spaces for distributed Python code; this is also the Emacs python-mode default.

Under any editor, mixing tabs and spaces is a bad idea. MSVC is no different in this respect, and is easily configured to use spaces: Take *Tools* → *Options* → *Tabs*, and for file type “Default” set “Tab size” and “Indent size” to 4, and select the “Insert spaces” radio button.

If you suspect mixed tabs and spaces are causing problems in leading whitespace, run Python with the `-t` switch or run `Tools/Scripts/tabnanny.py` to check a directory tree in batch mode.

## 6.9 How do I check for a keypress without blocking?

Use the `msvcrt` module. This is a standard Windows-specific extension module. It defines a function `kbhit()` which checks whether a keyboard hit is present, and `getch()` which gets one character without echoing it.

## 6.10 How do I emulate `os.kill()` in Windows?

Prior to Python 2.7 and 3.2, to terminate a process, you can use `ctypes`:

```
import ctypes

def kill(pid):
    """kill function for Win32"""
    kernel32 = ctypes.windll.kernel32
    handle = kernel32.OpenProcess(1, 0, pid)
    return (0 != kernel32.TerminateProcess(handle, 0))
```

In 2.7 and 3.2, `os.kill()` is implemented similar to the above function, with the additional feature of being able to send CTRL+C and CTRL+BREAK to console subprocesses which are designed to handle those signals. See `os.kill()` for further details.

### 6.11 Why does `os.path.isdir()` fail on NT shared directories?

In order to work correctly, `os.path.isdir()` requires a "\\\" at the end of the shared drive:

```
>>> import os
>>> os.path.isdir('\\\\\\rorschach\\public')
0
>>> os.path.isdir('\\\\\\rorschach\\public\\')
1
```

It helps to think of share points as being like drive letters. Example:

```
k: is not a directory
k:\ is a directory
k:\media is a directory
k:\media\ is not a directory
```

The same rules apply if you substitute "k:" with "\\conky\foo":

```
\\conky\foo is not a directory
\\conky\foo\ is a directory
\\conky\foo\media is a directory
\\conky\foo\media\ is not a directory
```

### 6.12 `cgi.py` (or other CGI programming) doesn't work sometimes on NT or win95!

Be sure you have the latest `python.exe`, that you are using `python.exe` rather than a GUI version of Python and that you have configured the server to execute

```
"...\\python.exe -u ..."
```

for the CGI execution. The `-u` (unbuffered) option on NT and Win95 prevents the interpreter from altering newlines in the standard input and output. Without it post/multipart requests will seem to have the wrong length and binary (e.g. GIF) responses may get garbled (resulting in broken images, PDF files, and other binary downloads failing).

### 6.13 Why doesn't `os.popen()` work in PythonWin on NT?

The reason that `os.popen()` doesn't work from within PythonWin is due to a bug in Microsoft's C Runtime Library (CRT). The CRT assumes you have a Win32 console attached to the process.

You should use the `win32pipe` module's `popen()` instead which doesn't depend on having an attached Win32 console.

Example:

```
import win32pipe
f = win32pipe.popen('dir /c c:\\')
print f.readlines()
f.close()
```

## 6.14 Why doesn't `os.popen()/win32pipe.popen()` work on Win9x?

There is a bug in Win9x that prevents `os.popen/win32pipe.popen*` from working. The good news is there is a way to work around this problem. The Microsoft Knowledge Base article that you need to lookup is: Q150956. You will find links to the knowledge base at: <http://support.microsoft.com/>.

## 6.15 `PyRun_SimpleFile()` crashes on Windows but not on Unix; why?

This is very sensitive to the compiler vendor, version and (perhaps) even options. If the `FILE*` structure in your embedding program isn't the same as is assumed by the Python interpreter it won't work.

The Python 1.5.\* DLLs (`python15.dll`) are all compiled with MS VC++ 5.0 and with multithreading-DLL options (`/MD`).

If you can't change compilers or flags, try using `Py_RunSimpleString()`. A trick to get it to run an arbitrary file is to construct a call to `execfile()` with the name of your file as argument.

Also note that you can not mix-and-match Debug and Release versions. If you wish to use the Debug Multithreaded DLL, then your module *must* have `_d` appended to the base name.

## 6.16 Importing `_tkinter` fails on Windows 95/98: why?

Sometimes, the import of `_tkinter` fails on Windows 95 or 98, complaining with a message like the following:

```
ImportError: DLL load failed: One of the library files needed
to run this application cannot be found.
```

It could be that you haven't installed Tcl/Tk, but if you did install Tcl/Tk, and the Wish application works correctly, the problem may be that its installer didn't manage to edit the `autoexec.bat` file correctly. It tries to add a statement that changes the `PATH` environment variable to include the Tcl/Tk 'bin' subdirectory, but sometimes this edit doesn't quite work. Opening it with notepad usually reveals what the problem is.

(One additional hint, noted by David Szafranski: you can't use long filenames here; e.g. use `C:\PROGRA~1\Tcl\bin` instead of `C:\Program Files\Tcl\bin`.)

## 6.17 How do I extract the downloaded documentation on Windows?

Sometimes, when you download the documentation package to a Windows machine using a web browser, the file extension of the saved file ends up being `.EXE`. This is a mistake; the extension should be `.TGZ`.

Simply rename the downloaded file to have the `.TGZ` extension, and WinZip will be able to handle it. (If your copy of WinZip doesn't, get a newer one from <http://www.winzip.com>.)

## 6.18 Missing `cw3215mt.dll` (or missing `cw3215.dll`)

Sometimes, when using Tkinter on Windows, you get an error that `cw3215mt.dll` or `cw3215.dll` is missing.

Cause: you have an old Tcl/Tk DLL built with cygwin in your path (probably `C:\Windows`). You must use the Tcl/Tk DLLs from the standard Tcl/Tk installation (Python 1.5.2 comes with one).

## 6.19 Warning about CTL3D32 version from installer

The Python installer issues a warning like this:

```
This version uses CTL3D32.DLL which is not the correct version.  
This version is used for windows NT applications only.
```

Tim Peters:

This is a Microsoft DLL, and a notorious source of problems. The message means what it says: you have the wrong version of this DLL for your operating system. The Python installation did not cause this – something else you installed previous to this overwrote the DLL that came with your OS (probably older shareware of some sort, but there’s no way to tell now). If you search for “CTL3D32” using any search engine (AltaVista, for example), you’ll find hundreds and hundreds of web pages complaining about the same problem with all sorts of installation programs. They’ll point you to ways to get the correct version reinstalled on your system (since Python doesn’t cause this, we can’t fix it).

David A Burton has written a little program to fix this. Go to <http://www.burtonsys.com/downloads.html> and click on “ctl3dfix.zip”.

# GRAPHIC USER INTERFACE FAQ

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## 7.1 What platform-independent GUI toolkits exist for Python?

Depending on what platform(s) you are aiming at, there are several.

### 7.1.1 Tkinter

Standard builds of Python include an object-oriented interface to the Tcl/Tk widget set, called Tkinter. This is probably the easiest to install and use. For more info about Tk, including pointers to the source, see the Tcl/Tk home page at <http://www.tcl.tk>. Tcl/Tk is fully portable to the MacOS, Windows, and Unix platforms.

### 7.1.2 wxWidgets

wxWidgets (<http://www.wxwidgets.org>) is a free, portable GUI class library written in C++ that provides a native look and feel on a number of platforms, with Windows, MacOS X, GTK, X11, all listed as current stable targets. Language bindings are available for a number of languages including Python, Perl, Ruby, etc.

wxPython (<http://www.wxpython.org>) is the Python binding for wxwidgets. While it often lags slightly behind the official wxWidgets releases, it also offers a number of features via pure Python extensions that are not available in other language bindings. There is an active wxPython user and developer community.

Both wxWidgets and wxPython are free, open source, software with permissive licences that allow their use in commercial products as well as in freeware or shareware.

### 7.1.3 Qt

There are bindings available for the Qt toolkit ([PyQt](#)) and for KDE ([PyKDE](#)). If you're writing open source software, you don't need to pay for PyQt, but if you want to write proprietary applications, you must buy a PyQt license from [Riverbank Computing](#) and (up to Qt 4.4; Qt 4.5 upwards is licensed under the LGPL license) a Qt license from [Trolltech](#).

### 7.1.4 Gtk+

PyGtk bindings for the [Gtk+](#) toolkit have been implemented by James Henstridge; see <http://www.pygtk.org>.

### 7.1.5 FLTK

Python bindings for the [FLTK](#) toolkit, a simple yet powerful and mature cross-platform windowing system, are available from the [PyFLTK](#) project.

### 7.1.6 FOX

A wrapper for the [FOX](#) toolkit called [FXpy](#) is available. FOX supports both Unix variants and Windows.

### 7.1.7 OpenGL

For OpenGL bindings, see [PyOpenGL](#).

## 7.2 What platform-specific GUI toolkits exist for Python?

The [Mac port](#) by Jack Jansen has a rich and ever-growing set of modules that support the native Mac toolbox calls. The port supports MacOS X's Carbon libraries.

By installing the [PyObjc Objective-C bridge](#), Python programs can use MacOS X's Cocoa libraries. See the documentation that comes with the Mac port.

[Pythonwin](#) by Mark Hammond includes an interface to the Microsoft Foundation Classes and a Python programming environment that's written mostly in Python using the MFC classes.

## 7.3 Tkinter questions

### 7.3.1 How do I freeze Tkinter applications?

Freeze is a tool to create stand-alone applications. When freezing Tkinter applications, the applications will not be truly stand-alone, as the application will still need the Tcl and Tk libraries.

One solution is to ship the application with the Tcl and Tk libraries, and point to them at run-time using the `TCL_LIBRARY` and `TK_LIBRARY` environment variables.

To get truly stand-alone applications, the Tcl scripts that form the library have to be integrated into the application as well. One tool supporting that is SAM (stand-alone modules), which is part of the Tix distribution (<http://tix.sourceforge.net/>).

Build Tix with SAM enabled, perform the appropriate call to `Tclsam_init()`, etc. inside Python's `Modules/tkappinit.c`, and link with `libtclsam` and `libtkSAM` (you might include the Tix libraries as well).

### 7.3.2 Can I have Tk events handled while waiting for I/O?

Yes, and you don't even need threads! But you'll have to restructure your I/O code a bit. Tk has the equivalent of Xt's `XtAddInput()` call, which allows you to register a callback function which will be called from the Tk mainloop when I/O is possible on a file descriptor. Here's what you need:

```
from Tkinter import tkinter
tkinter.createfilehandler(file, mask, callback)
```

The file may be a Python file or socket object (actually, anything with a `fileno()` method), or an integer file descriptor. The mask is one of the constants `tkinter.READABLE` or `tkinter.WRITABLE`. The callback is called as follows:

```
callback(file, mask)
```

You must unregister the callback when you're done, using

```
tkinter.deletefilehandler(file)
```

Note: since you don't know *how many bytes* are available for reading, you can't use the Python file object's `read` or `readline` methods, since these will insist on reading a predefined number of bytes. For sockets, the `recv()` or `recvfrom()` methods will work fine; for other files, use `os.read(file.fileno(), maxbytecount)`.

### 7.3.3 I can't get key bindings to work in Tkinter: why?

An often-heard complaint is that event handlers bound to events with the `bind()` method don't get handled even when the appropriate key is pressed.

The most common cause is that the widget to which the binding applies doesn't have "keyboard focus". Check out the Tk documentation for the `focus` command. Usually a widget is given the keyboard focus by clicking in it (but not for labels; see the `takefocus` option).



# “WHY IS PYTHON INSTALLED ON MY COMPUTER?” FAQ

## 8.1 What is Python?

Python is a programming language. It’s used for many different applications. It’s used in some high schools and colleges as an introductory programming language because Python is easy to learn, but it’s also used by professional software developers at places such as Google, NASA, and Lucasfilm Ltd.

If you wish to learn more about Python, start with the [Beginner’s Guide to Python](#).

## 8.2 Why is Python installed on my machine?

If you find Python installed on your system but don’t remember installing it, there are several possible ways it could have gotten there.

- Perhaps another user on the computer wanted to learn programming and installed it; you’ll have to figure out who’s been using the machine and might have installed it.
- A third-party application installed on the machine might have been written in Python and included a Python installation. For a home computer, the most common such application is [PySol](#), a solitaire game that includes over 1000 different games and variations.
- Some Windows machines also have Python installed. At this writing we’re aware of computers from Hewlett-Packard and Compaq that include Python. Apparently some of HP/Compaq’s administrative tools are written in Python.
- All Apple computers running Mac OS X have Python installed; it’s included in the base installation.

## 8.3 Can I delete Python?

That depends on where Python came from.

If someone installed it deliberately, you can remove it without hurting anything. On Windows, use the Add/Remove Programs icon in the Control Panel.

If Python was installed by a third-party application, you can also remove it, but that application will no longer work. You should use that application’s uninstaller rather than removing Python directly.

If Python came with your operating system, removing it is not recommended. If you remove it, whatever tools were written in Python will no longer run, and some of them might be important to you. Reinstalling the whole system would then be required to fix things again.

---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**. . .** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

---

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Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
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- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

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Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

Continued on next page

Table C.1 – continued from previous page

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

---

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

```
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```

```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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-----
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```

### C.3.4 MD5 message digest algorithm

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
(section A.5) but excluding the rest of Appendix A. It does not include
any code or documentation that is identified in the RFC as being
copyrighted.
```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
           references to Ghostscript; clarified derivation from RFC 1321;
           now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

### C.3.5 Asynchronous socket services

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### C.3.8 UUencode and UUdecode functions

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Modified by Jack Jansen, CWI, July 1995:

- Use `binascii` module to do the actual line-by-line conversion between `ascii` and `binary`. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

### C.3.9 XML Remote Procedure Calls

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The XML-RPC client interface is

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### C.3.10 `test_epoll`

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jloup@gzip.org

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# The Python Library Reference

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
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While *reference-index* describes the exact syntax and semantics of the Python language, this library reference manual describes the standard library that is distributed with Python. It also describes some of the optional components that are commonly included in Python distributions.

Python's standard library is very extensive, offering a wide range of facilities as indicated by the long table of contents listed below. The library contains built-in modules (written in C) that provide access to system functionality such as file I/O that would otherwise be inaccessible to Python programmers, as well as modules written in Python that provide standardized solutions for many problems that occur in everyday programming. Some of these modules are explicitly designed to encourage and enhance the portability of Python programs by abstracting away platform-specifics into platform-neutral APIs.

The Python installers for the Windows platform usually includes the entire standard library and often also include many additional components. For Unix-like operating systems Python is normally provided as a collection of packages, so it may be necessary to use the packaging tools provided with the operating system to obtain some or all of the optional components.

In addition to the standard library, there is a growing collection of several thousand components (from individual programs and modules to packages and entire application development frameworks), available from the [Python Package Index](#).



# INTRODUCTION

The “Python library” contains several different kinds of components.

It contains data types that would normally be considered part of the “core” of a language, such as numbers and lists. For these types, the Python language core defines the form of literals and places some constraints on their semantics, but does not fully define the semantics. (On the other hand, the language core does define syntactic properties like the spelling and priorities of operators.)

The library also contains built-in functions and exceptions — objects that can be used by all Python code without the need of an `import` statement. Some of these are defined by the core language, but many are not essential for the core semantics and are only described here.

The bulk of the library, however, consists of a collection of modules. There are many ways to dissect this collection. Some modules are written in C and built in to the Python interpreter; others are written in Python and imported in source form. Some modules provide interfaces that are highly specific to Python, like printing a stack trace; some provide interfaces that are specific to particular operating systems, such as access to specific hardware; others provide interfaces that are specific to a particular application domain, like the World Wide Web. Some modules are available in all versions and ports of Python; others are only available when the underlying system supports or requires them; yet others are available only when a particular configuration option was chosen at the time when Python was compiled and installed.

This manual is organized “from the inside out:” it first describes the built-in data types, then the built-in functions and exceptions, and finally the modules, grouped in chapters of related modules. The ordering of the chapters as well as the ordering of the modules within each chapter is roughly from most relevant to least important.

This means that if you start reading this manual from the start, and skip to the next chapter when you get bored, you will get a reasonable overview of the available modules and application areas that are supported by the Python library. Of course, you don’t *have* to read it like a novel — you can also browse the table of contents (in front of the manual), or look for a specific function, module or term in the index (in the back). And finally, if you enjoy learning about random subjects, you choose a random page number (see module `random`) and read a section or two. Regardless of the order in which you read the sections of this manual, it helps to start with chapter *Built-in Functions*, as the remainder of the manual assumes familiarity with this material.

Let the show begin!



# BUILT-IN FUNCTIONS

The Python interpreter has a number of functions built into it that are always available. They are listed here in alphabetical order.

Built-in Functions				
abs()	divmod()	input()	open()	staticmethod()
all()	enumerate()	int()	ord()	str()
any()	eval()	isinstance()	pow()	sum()
basestring()	execfile()	issubclass()	print()	super()
bin()	file()	iter()	property()	tuple()
bool()	filter()	len()	range()	type()
bytearray()	float()	list()	raw_input()	unichr()
callable()	format()	locals()	reduce()	unicode()
chr()	frozenset()	long()	reload()	vars()
classmethod()	getattr()	map()	repr()	xrange()
cmp()	globals()	max()	reversed()	zip()
compile()	hasattr()	memoryview()	round()	__import__()
complex()	hash()	min()	set()	apply()
delattr()	help()	next()	setattr()	buffer()
dict()	hex()	object()	slice()	coerce()
dir()	id()	oct()	sorted()	intern()

## abs(x)

Return the absolute value of a number. The argument may be a plain or long integer or a floating point number. If the argument is a complex number, its magnitude is returned.

## all(iterable)

Return True if all elements of the *iterable* are true (or if the iterable is empty). Equivalent to:

```
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```

New in version 2.5.

## any(iterable)

Return True if any element of the *iterable* is true. If the iterable is empty, return False. Equivalent to:

```
def any(iterable):
    for element in iterable:
        if element:
```

```
        return True
    return False
```

New in version 2.5.

### **basestring**()

This abstract type is the superclass for `str` and `unicode`. It cannot be called or instantiated, but it can be used to test whether an object is an instance of `str` or `unicode`. `isinstance(obj, basestring)` is equivalent to `isinstance(obj, (str, unicode))`. New in version 2.3.

### **bin**(x)

Convert an integer number to a binary string. The result is a valid Python expression. If `x` is not a Python `int` object, it has to define an `__index__()` method that returns an integer. New in version 2.6.

### **bool**([x])

Convert a value to a Boolean, using the standard truth testing procedure. If `x` is false or omitted, this returns `False`; otherwise it returns `True`. `bool` is also a class, which is a subclass of `int`. Class `bool` cannot be subclassed further. Its only instances are `False` and `True`.

New in version 2.2.1.Changed in version 2.3: If no argument is given, this function returns `False`.

### **bytearray**([source[, encoding[, errors]]])

Return a new array of bytes. The `bytearray` type is a mutable sequence of integers in the range  $0 \leq x < 256$ . It has most of the usual methods of mutable sequences, described in *Mutable Sequence Types*, as well as most methods that the `str` type has, see *String Methods*.

The optional `source` parameter can be used to initialize the array in a few different ways:

- If it is a *string*, you must also give the `encoding` (and optionally, `errors`) parameters; `bytearray()` then converts the string to bytes using `str.encode()`.
- If it is an *integer*, the array will have that size and will be initialized with null bytes.
- If it is an object conforming to the *buffer* interface, a read-only buffer of the object will be used to initialize the bytes array.
- If it is an *iterable*, it must be an iterable of integers in the range  $0 \leq x < 256$ , which are used as the initial contents of the array.

Without an argument, an array of size 0 is created. New in version 2.6.

### **callable**(object)

Return `True` if the `object` argument appears callable, `False` if not. If this returns true, it is still possible that a call fails, but if it is false, calling `object` will never succeed. Note that classes are callable (calling a class returns a new instance); class instances are callable if they have a `__call__()` method.

### **chr**(i)

Return a string of one character whose ASCII code is the integer `i`. For example, `chr(97)` returns the string `'a'`. This is the inverse of `ord()`. The argument must be in the range `[0..255]`, inclusive; `ValueError` will be raised if `i` is outside that range. See also `unichr()`.

### **classmethod**(function)

Return a class method for `function`.

A class method receives the class as implicit first argument, just like an instance method receives the instance. To declare a class method, use this idiom:

```
class C:
    @classmethod
    def f(cls, arg1, arg2, ...): ...
```

The `@classmethod` form is a function *decorator* – see the description of function definitions in *function* for details.

It can be called either on the class (such as `C.f()`) or on an instance (such as `C().f()`). The instance is ignored except for its class. If a class method is called for a derived class, the derived class object is passed as the implied first argument.

Class methods are different than C++ or Java static methods. If you want those, see `staticmethod()` in this section.

For more information on class methods, consult the documentation on the standard type hierarchy in *types*. New in version 2.2.Changed in version 2.4: Function decorator syntax added.

**cmp**(*x*, *y*)

Compare the two objects *x* and *y* and return an integer according to the outcome. The return value is negative if  $x < y$ , zero if  $x == y$  and strictly positive if  $x > y$ .

**compile**(*source*, *filename*, *mode*[, *flags*[, *dont\_inherit*]])

Compile the *source* into a code or AST object. Code objects can be executed by an `exec` statement or evaluated by a call to `eval()`. *source* can either be a string or an AST object. Refer to the `ast` module documentation for information on how to work with AST objects.

The *filename* argument should give the file from which the code was read; pass some recognizable value if it wasn't read from a file ('<string>' is commonly used).

The *mode* argument specifies what kind of code must be compiled; it can be 'exec' if *source* consists of a sequence of statements, 'eval' if it consists of a single expression, or 'single' if it consists of a single interactive statement (in the latter case, expression statements that evaluate to something other than `None` will be printed).

The optional arguments *flags* and *dont\_inherit* control which future statements (see [PEP 236](#)) affect the compilation of *source*. If neither is present (or both are zero) the code is compiled with those future statements that are in effect in the code that is calling `compile`. If the *flags* argument is given and *dont\_inherit* is not (or is zero) then the future statements specified by the *flags* argument are used in addition to those that would be used anyway. If *dont\_inherit* is a non-zero integer then the *flags* argument is it – the future statements in effect around the call to `compile` are ignored.

Future statements are specified by bits which can be bitwise ORed together to specify multiple statements. The bitfield required to specify a given feature can be found as the `compiler_flag` attribute on the `_Feature` instance in the `__future__` module.

This function raises `SyntaxError` if the compiled source is invalid, and `TypeError` if the source contains null bytes.

---

**Note:** When compiling a string with multi-line code in 'single' or 'eval' mode, input must be terminated by at least one newline character. This is to facilitate detection of incomplete and complete statements in the `code` module.

---

Changed in version 2.3: The *flags* and *dont\_inherit* arguments were added.Changed in version 2.6: Support for compiling AST objects.Changed in version 2.7: Allowed use of Windows and Mac newlines. Also input in 'exec' mode does not have to end in a newline anymore.

**complex**([*real*[, *imag*]])

Create a complex number with the value  $real + imag*j$  or convert a string or number to a complex number. If the first parameter is a string, it will be interpreted as a complex number and the function must be called without a second parameter. The second parameter can never be a string. Each argument may be any numeric type (including complex). If *imag* is omitted, it defaults to zero and the function serves as a numeric conversion function like `int()`, `long()` and `float()`. If both arguments are omitted, returns `0j`.

---

**Note:** When converting from a string, the string must not contain whitespace around the central + or - operator. For example, `complex('1+2j')` is fine, but `complex('1 + 2j')` raises `ValueError`.

---

The complex type is described in *Numeric Types — int, float, long, complex*.

**delattr** (*object*, *name*)

This is a relative of `setattr()`. The arguments are an object and a string. The string must be the name of one of the object's attributes. The function deletes the named attribute, provided the object allows it. For example, `delattr(x, 'foobar')` is equivalent to `del x.foobar`.

**dict** ([*arg*])

Create a new data dictionary, optionally with items taken from *arg*. The dictionary type is described in *Mapping Types — dict*.

For other containers see the built in `list`, `set`, and `tuple` classes, and the `collections` module.

**dir** ([*object*])

Without arguments, return the list of names in the current local scope. With an argument, attempt to return a list of valid attributes for that object.

If the object has a method named `__dir__()`, this method will be called and must return the list of attributes. This allows objects that implement a custom `__getattr__()` or `__getattribute__()` function to customize the way `dir()` reports their attributes.

If the object does not provide `__dir__()`, the function tries its best to gather information from the object's `__dict__` attribute, if defined, and from its type object. The resulting list is not necessarily complete, and may be inaccurate when the object has a custom `__getattr__()`.

The default `dir()` mechanism behaves differently with different types of objects, as it attempts to produce the most relevant, rather than complete, information:

- If the object is a module object, the list contains the names of the module's attributes.
- If the object is a type or class object, the list contains the names of its attributes, and recursively of the attributes of its bases.
- Otherwise, the list contains the object's attributes' names, the names of its class's attributes, and recursively of the attributes of its class's base classes.

The resulting list is sorted alphabetically. For example:

```
>>> import struct
>>> dir()      # show the names in the module namespace
['__builtins__', '__doc__', '__name__', 'struct']
>>> dir(struct)  # show the names in the struct module
['Struct', '__builtins__', '__doc__', '__file__', '__name__',
 '__package__', '__clearcache__', 'calcsize', 'error', 'pack', 'pack_into',
 'unpack', 'unpack_from']
>>> class Shape(object):
    def __dir__(self):
        return ['area', 'perimeter', 'location']
>>> s = Shape()
>>> dir(s)
['area', 'perimeter', 'location']
```

---

**Note:** Because `dir()` is supplied primarily as a convenience for use at an interactive prompt, it tries to supply an interesting set of names more than it tries to supply a rigorously or consistently defined set of names, and its

detailed behavior may change across releases. For example, metaclass attributes are not in the result list when the argument is a class.

### **divmod**(*a*, *b*)

Take two (non complex) numbers as arguments and return a pair of numbers consisting of their quotient and remainder when using long division. With mixed operand types, the rules for binary arithmetic operators apply. For plain and long integers, the result is the same as ( $a // b$ ,  $a \% b$ ). For floating point numbers the result is ( $q$ ,  $a \% b$ ), where  $q$  is usually `math.floor(a / b)` but may be 1 less than that. In any case  $q * b + a \% b$  is very close to  $a$ , if  $a \% b$  is non-zero it has the same sign as  $b$ , and  $0 \leq \text{abs}(a \% b) < \text{abs}(b)$ . Changed in version 2.3: Using `divmod()` with complex numbers is deprecated.

### **enumerate**(*sequence*, *start*=0)

Return an enumerate object. *sequence* must be a sequence, an *iterator*, or some other object which supports iteration. The `next()` method of the iterator returned by `enumerate()` returns a tuple containing a count (from *start* which defaults to 0) and the values obtained from iterating over *sequence*:

```
>>> seasons = ['Spring', 'Summer', 'Fall', 'Winter']
>>> list(enumerate(seasons))
[(0, 'Spring'), (1, 'Summer'), (2, 'Fall'), (3, 'Winter')]
>>> list(enumerate(seasons, start=1))
[(1, 'Spring'), (2, 'Summer'), (3, 'Fall'), (4, 'Winter')]
```

Equivalent to:

```
def enumerate(sequence, start=0):
    n = start
    for elem in sequence:
        yield n, elem
        n += 1
```

New in version 2.3.Changed in version 2.6: The *start* parameter was added.

### **eval**(*expression*[, *globals*[, *locals* ]])

The arguments are a string and optional globals and locals. If provided, *globals* must be a dictionary. If provided, *locals* can be any mapping object. Changed in version 2.4: formerly *locals* was required to be a dictionary. The *expression* argument is parsed and evaluated as a Python expression (technically speaking, a condition list) using the *globals* and *locals* dictionaries as global and local namespace. If the *globals* dictionary is present and lacks `'__builtins__'`, the current globals are copied into *globals* before *expression* is parsed. This means that *expression* normally has full access to the standard `__builtin__` module and restricted environments are propagated. If the *locals* dictionary is omitted it defaults to the *globals* dictionary. If both dictionaries are omitted, the expression is executed in the environment where `eval()` is called. The return value is the result of the evaluated expression. Syntax errors are reported as exceptions. Example:

```
>>> x = 1
>>> print eval('x+1')
2
```

This function can also be used to execute arbitrary code objects (such as those created by `compile()`). In this case pass a code object instead of a string. If the code object has been compiled with `'exec'` as the *mode* argument, `eval()`'s return value will be `None`.

Hints: dynamic execution of statements is supported by the `exec` statement. Execution of statements from a file is supported by the `execfile()` function. The `globals()` and `locals()` functions returns the current global and local dictionary, respectively, which may be useful to pass around for use by `eval()` or `execfile()`.

See `ast.literal_eval()` for a function that can safely evaluate strings with expressions containing only literals.

**execfile** (*filename* [, *globals* [, *locals* ] ])

This function is similar to the `exec` statement, but parses a file instead of a string. It is different from the `import` statement in that it does not use the module administration — it reads the file unconditionally and does not create a new module.<sup>1</sup>

The arguments are a file name and two optional dictionaries. The file is parsed and evaluated as a sequence of Python statements (similarly to a module) using the *globals* and *locals* dictionaries as global and local namespace. If provided, *locals* can be any mapping object. Remember that at module level, *globals* and *locals* are the same dictionary. If two separate objects are passed as *globals* and *locals*, the code will be executed as if it were embedded in a class definition. Changed in version 2.4: formerly *locals* was required to be a dictionary. If the *locals* dictionary is omitted it defaults to the *globals* dictionary. If both dictionaries are omitted, the expression is executed in the environment where `execfile()` is called. The return value is `None`.

---

**Note:** The default *locals* act as described for function `locals()` below: modifications to the default *locals* dictionary should not be attempted. Pass an explicit *locals* dictionary if you need to see effects of the code on *locals* after function `execfile()` returns. `execfile()` cannot be used reliably to modify a function's *locals*.

---

**file** (*name* [, *mode* [, *buffering* ] ])

Constructor function for the `file` type, described further in section *File Objects*. The constructor's arguments are the same as those of the `open()` built-in function described below.

When opening a file, it's preferable to use `open()` instead of invoking this constructor directly. `file` is more suited to type testing (for example, writing `isinstance(f, file)`). New in version 2.2.

**filter** (*function*, *iterable*)

Construct a list from those elements of *iterable* for which *function* returns true. *iterable* may be either a sequence, a container which supports iteration, or an iterator. If *iterable* is a string or a tuple, the result also has that type; otherwise it is always a list. If *function* is `None`, the identity function is assumed, that is, all elements of *iterable* that are false are removed.

Note that `filter(function, iterable)` is equivalent to `[item for item in iterable if function(item)]` if *function* is not `None` and `[item for item in iterable if item]` if *function* is `None`.

See `itertools.ifilter()` and `itertools.ifilterfalse()` for iterator versions of this function, including a variation that filters for elements where the *function* returns false.

**float** ([*x*])

Convert a string or a number to floating point. If the argument is a string, it must contain a possibly signed decimal or floating point number, possibly embedded in whitespace. The argument may also be `[+-]nan` or `[+-]inf`. Otherwise, the argument may be a plain or long integer or a floating point number, and a floating point number with the same value (within Python's floating point precision) is returned. If no argument is given, returns `0.0`.

---

**Note:** When passing in a string, values for NaN and Infinity may be returned, depending on the underlying C library. Float accepts the strings `nan`, `inf` and `-inf` for NaN and positive or negative infinity. The case and a leading `+` are ignored as well as a leading `-` is ignored for NaN. Float always represents NaN and infinity as `nan`, `inf` or `-inf`.

---

The float type is described in *Numeric Types — int, float, long, complex*.

---

<sup>1</sup> It is used relatively rarely so does not warrant being made into a statement.

**format** (*value* [, *format\_spec* ])

Convert a *value* to a “formatted” representation, as controlled by *format\_spec*. The interpretation of *format\_spec* will depend on the type of the *value* argument, however there is a standard formatting syntax that is used by most built-in types: *Format Specification Mini-Language*.

---

**Note:** `format(value, format_spec)` merely calls `value.__format__(format_spec)`.

---

New in version 2.6.

**frozenset** ([*iterable* ])

Return a frozenset object, optionally with elements taken from *iterable*. The frozenset type is described in *Set Types — set, frozenset*.

For other containers see the built in `dict`, `list`, and `tuple` classes, and the `collections` module. New in version 2.4.

**getattr** (*object*, *name* [, *default* ])

Return the value of the named attribute of *object*. *name* must be a string. If the string is the name of one of the object’s attributes, the result is the value of that attribute. For example, `getattr(x, 'foobar')` is equivalent to `x.foobar`. If the named attribute does not exist, *default* is returned if provided, otherwise `AttributeError` is raised.

**globals** ()

Return a dictionary representing the current global symbol table. This is always the dictionary of the current module (inside a function or method, this is the module where it is defined, not the module from which it is called).

**hasattr** (*object*, *name*)

The arguments are an object and a string. The result is `True` if the string is the name of one of the object’s attributes, `False` if not. (This is implemented by calling `getattr(object, name)` and seeing whether it raises an exception or not.)

**hash** (*object*)

Return the hash value of the object (if it has one). Hash values are integers. They are used to quickly compare dictionary keys during a dictionary lookup. Numeric values that compare equal have the same hash value (even if they are of different types, as is the case for 1 and 1.0).

**help** ([*object* ])

Invoke the built-in help system. (This function is intended for interactive use.) If no argument is given, the interactive help system starts on the interpreter console. If the argument is a string, then the string is looked up as the name of a module, function, class, method, keyword, or documentation topic, and a help page is printed on the console. If the argument is any other kind of object, a help page on the object is generated.

This function is added to the built-in namespace by the `site` module. New in version 2.2.

**hex** (*x*)

Convert an integer number (of any size) to a hexadecimal string. The result is a valid Python expression.

---

**Note:** To obtain a hexadecimal string representation for a float, use the `float.hex()` method.

---

Changed in version 2.4: Formerly only returned an unsigned literal.

**id** (*object*)

Return the “identity” of an object. This is an integer (or long integer) which is guaranteed to be unique and constant for this object during its lifetime. Two objects with non-overlapping lifetimes may have the same `id()` value.

**CPython implementation detail:** This is the address of the object in memory.

**input** (*[prompt]*)Equivalent to `eval(raw_input(prompt))`.

This function does not catch user errors. If the input is not syntactically valid, a `SyntaxError` will be raised. Other exceptions may be raised if there is an error during evaluation.

If the `readline` module was loaded, then `input()` will use it to provide elaborate line editing and history features.

Consider using the `raw_input()` function for general input from users.

**int** (*[x[, base]]*)

Convert a string or number to a plain integer. If the argument is a string, it must contain a possibly signed decimal number representable as a Python integer, possibly embedded in whitespace. The *base* parameter gives the base for the conversion (which is 10 by default) and may be any integer in the range [2, 36], or zero. If *base* is zero, the proper radix is determined based on the contents of string; the interpretation is the same as for integer literals. (See *numbers*.) If *base* is specified and *x* is not a string, `TypeError` is raised. Otherwise, the argument may be a plain or long integer or a floating point number. Conversion of floating point numbers to integers truncates (towards zero). If the argument is outside the integer range a long object will be returned instead. If no arguments are given, returns 0.

The integer type is described in *Numeric Types — int, float, long, complex*.

**isinstance** (*object, classinfo*)

Return true if the *object* argument is an instance of the *classinfo* argument, or of a (direct, indirect or *virtual*) subclass thereof. Also return true if *classinfo* is a type object (new-style class) and *object* is an object of that type or of a (direct, indirect or *virtual*) subclass thereof. If *object* is not a class instance or an object of the given type, the function always returns false. If *classinfo* is neither a class object nor a type object, it may be a tuple of class or type objects, or may recursively contain other such tuples (other sequence types are not accepted). If *classinfo* is not a class, type, or tuple of classes, types, and such tuples, a `TypeError` exception is raised. Changed in version 2.2: Support for a tuple of type information was added.

**issubclass** (*class, classinfo*)

Return true if *class* is a subclass (direct, indirect or *virtual*) of *classinfo*. A class is considered a subclass of itself. *classinfo* may be a tuple of class objects, in which case every entry in *classinfo* will be checked. In any other case, a `TypeError` exception is raised. Changed in version 2.3: Support for a tuple of type information was added.

**iter** (*o[, sentinel]*)

Return an *iterator* object. The first argument is interpreted very differently depending on the presence of the second argument. Without a second argument, *o* must be a collection object which supports the iteration protocol (the `__iter__()` method), or it must support the sequence protocol (the `__getitem__()` method with integer arguments starting at 0). If it does not support either of those protocols, `TypeError` is raised. If the second argument, *sentinel*, is given, then *o* must be a callable object. The iterator created in this case will call *o* with no arguments for each call to its `next()` method; if the value returned is equal to *sentinel*, `StopIteration` will be raised, otherwise the value will be returned.

One useful application of the second form of `iter()` is to read lines of a file until a certain line is reached. The following example reads a file until the `readline()` method returns an empty string:

```
with open('mydata.txt') as fp:
    for line in iter(fp.readline, ''):
        process_line(line)
```

New in version 2.2.

**len** (*s*)

Return the length (the number of items) of an object. The argument may be a sequence (string, tuple or list) or a mapping (dictionary).

**list** (*iterable* )

Return a list whose items are the same and in the same order as *iterable*'s items. *iterable* may be either a sequence, a container that supports iteration, or an iterator object. If *iterable* is already a list, a copy is made and returned, similar to `iterable[:]`. For instance, `list('abc')` returns `['a', 'b', 'c']` and `list(1, 2, 3)` returns `[1, 2, 3]`. If no argument is given, returns a new empty list, `[]`.

`list` is a mutable sequence type, as documented in *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange*. For other containers see the built in `dict`, `set`, and `tuple` classes, and the `collections` module.

**locals** ()

Update and return a dictionary representing the current local symbol table. Free variables are returned by `locals()` when it is called in function blocks, but not in class blocks.

---

**Note:** The contents of this dictionary should not be modified; changes may not affect the values of local and free variables used by the interpreter.

---

**long** (*x* [, *base* ] )

Convert a string or number to a long integer. If the argument is a string, it must contain a possibly signed number of arbitrary size, possibly embedded in whitespace. The *base* argument is interpreted in the same way as for `int()`, and may only be given when *x* is a string. Otherwise, the argument may be a plain or long integer or a floating point number, and a long integer with the same value is returned. Conversion of floating point numbers to integers truncates (towards zero). If no arguments are given, returns `0L`.

The long type is described in *Numeric Types — int, float, long, complex*.

**map** (*function*, *iterable*, ...)

Apply *function* to every item of *iterable* and return a list of the results. If additional *iterable* arguments are passed, *function* must take that many arguments and is applied to the items from all iterables in parallel. If one iterable is shorter than another it is assumed to be extended with `None` items. If *function* is `None`, the identity function is assumed; if there are multiple arguments, `map()` returns a list consisting of tuples containing the corresponding items from all iterables (a kind of transpose operation). The *iterable* arguments may be a sequence or any iterable object; the result is always a list.

**max** (*iterable* [, *key* ])**max** (*arg1*, *arg2*, \**args* [, *key* ])

Return the largest item in an iterable or the largest of two or more arguments.

If one positional argument is provided, *iterable* must be a non-empty iterable (such as a non-empty string, tuple or list). The largest item in the iterable is returned. If two or more positional arguments are provided, the largest of the positional arguments is returned.

The optional *key* argument specifies a one-argument ordering function like that used for `list.sort()`. The *key* argument, if supplied, must be in keyword form (for example, `max(a, b, c, key=func)`). Changed in version 2.5: Added support for the optional *key* argument.

**memoryview** (*obj*)

Return a “memory view” object created from the given argument. See *memoryview type* for more information.

**min** (*iterable* [, *key* ])**min** (*arg1*, *arg2*, \**args* [, *key* ])

Return the smallest item in an iterable or the smallest of two or more arguments.

If one positional argument is provided, *iterable* must be a non-empty iterable (such as a non-empty string, tuple or list). The smallest item in the iterable is returned. If two or more positional arguments are provided, the smallest of the positional arguments is returned.

The optional *key* argument specifies a one-argument ordering function like that used for `list.sort()`. The *key* argument, if supplied, must be in keyword form (for example, `min(a, b, c, key=func)`). Changed in version 2.5: Added support for the optional *key* argument.

**next** (*iterator* [, *default* ])

Retrieve the next item from the *iterator* by calling its `next()` method. If *default* is given, it is returned if the iterator is exhausted, otherwise `StopIteration` is raised. New in version 2.6.

**object** ()

Return a new featureless object. `object` is a base for all new style classes. It has the methods that are common to all instances of new style classes. New in version 2.2. Changed in version 2.3: This function does not accept any arguments. Formerly, it accepted arguments but ignored them.

**oct** (*x*)

Convert an integer number (of any size) to an octal string. The result is a valid Python expression. Changed in version 2.4: Formerly only returned an unsigned literal.

**open** (*name* [, *mode* [, *buffering* ] ])

Open a file, returning an object of the `file` type described in section [File Objects](#). If the file cannot be opened, `IOError` is raised. When opening a file, it's preferable to use `open()` instead of invoking the `file` constructor directly.

The first two arguments are the same as for `stdio`'s `fopen()`: *name* is the file name to be opened, and *mode* is a string indicating how the file is to be opened.

The most commonly-used values of *mode* are `'r'` for reading, `'w'` for writing (truncating the file if it already exists), and `'a'` for appending (which on *some* Unix systems means that *all* writes append to the end of the file regardless of the current seek position). If *mode* is omitted, it defaults to `'r'`. The default is to use text mode, which may convert `'\n'` characters to a platform-specific representation on writing and back on reading. Thus, when opening a binary file, you should append `'b'` to the *mode* value to open the file in binary mode, which will improve portability. (Appending `'b'` is useful even on systems that don't treat binary and text files differently, where it serves as documentation.) See below for more possible values of *mode*.

The optional *buffering* argument specifies the file's desired buffer size: 0 means unbuffered, 1 means line buffered, any other positive value means use a buffer of (approximately) that size. A negative *buffering* means to use the system default, which is usually line buffered for tty devices and fully buffered for other files. If omitted, the system default is used. <sup>2</sup>

Modes `'r+'`, `'w+'` and `'a+'` open the file for updating (note that `'w+'` truncates the file). Append `'b'` to the mode to open the file in binary mode, on systems that differentiate between binary and text files; on systems that don't have this distinction, adding the `'b'` has no effect.

In addition to the standard `fopen()` values *mode* may be `'U'` or `'rU'`. Python is usually built with *universal newlines* support; supplying `'U'` opens the file as a text file, but lines may be terminated by any of the following: the Unix end-of-line convention `'\n'`, the Macintosh convention `'\r'`, or the Windows convention `'\r\n'`. All of these external representations are seen as `'\n'` by the Python program. If Python is built without universal newlines support a *mode* with `'U'` is the same as normal text mode. Note that file objects so opened also have an attribute called `newlines` which has a value of `None` (if no newlines have yet been seen), `'\n'`, `'\r'`, `'\r\n'`, or a tuple containing all the newline types seen.

Python enforces that the mode, after stripping `'U'`, begins with `'r'`, `'w'` or `'a'`.

Python provides many file handling modules including `fileinput`, `os`, `os.path`, `tempfile`, and `shutil`. Changed in version 2.5: Restriction on first letter of mode string introduced.

**ord** (*c*)

Given a string of length one, return an integer representing the Unicode code point of the character when the argument is a unicode object, or the value of the byte when the argument is an 8-bit string. For example, `ord('a')` returns the integer 97, `ord(u'\u2020')` returns 8224. This is the inverse of `chr()` for 8-bit strings and of `unichr()` for unicode objects. If a unicode argument is given and Python was built with UCS2

---

<sup>2</sup> Specifying a buffer size currently has no effect on systems that don't have `setvbuf()`. The interface to specify the buffer size is not done using a method that calls `setvbuf()`, because that may dump core when called after any I/O has been performed, and there's no reliable way to determine whether this is the case.

Unicode, then the character's code point must be in the range [0..65535] inclusive; otherwise the string length is two, and a `TypeError` will be raised.

**pow**(*x*, *y*[, *z*])

Return *x* to the power *y*; if *z* is present, return *x* to the power *y*, modulo *z* (computed more efficiently than `pow(x, y) % z`). The two-argument form `pow(x, y)` is equivalent to using the power operator: `x**y`.

The arguments must have numeric types. With mixed operand types, the coercion rules for binary arithmetic operators apply. For int and long int operands, the result has the same type as the operands (after coercion) unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, `10**2` returns 100, but `10**−2` returns 0.01. (This last feature was added in Python 2.2. In Python 2.1 and before, if both arguments were of integer types and the second argument was negative, an exception was raised.) If the second argument is negative, the third argument must be omitted. If *z* is present, *x* and *y* must be of integer types, and *y* must be non-negative. (This restriction was added in Python 2.2. In Python 2.1 and before, floating 3-argument `pow()` returned platform-dependent results depending on floating-point rounding accidents.)

**print**(*\*objects*, *sep*=' ', *end*='\n', *file*=`sys.stdout`)

Print *objects* to the stream *file*, separated by *sep* and followed by *end*. *sep*, *end* and *file*, if present, must be given as keyword arguments.

All non-keyword arguments are converted to strings like `str()` does and written to the stream, separated by *sep* and followed by *end*. Both *sep* and *end* must be strings; they can also be `None`, which means to use the default values. If no *objects* are given, `print()` will just write *end*.

The *file* argument must be an object with a `write(string)` method; if it is not present or `None`, `sys.stdout` will be used. Output buffering is determined by *file*. Use `file.flush()` to ensure, for instance, immediate appearance on a screen.

---

**Note:** This function is not normally available as a built-in since the name `print` is recognized as the `print` statement. To disable the statement and use the `print()` function, use this future statement at the top of your module:

```
from __future__ import print_function
```

---

New in version 2.6.

**property**([*fget*[, *fset*[, *fdel*[, *doc*]]]])

Return a property attribute for *new-style classes* (classes that derive from `object`).

*fget* is a function for getting an attribute value, likewise *fset* is a function for setting, and *fdel* a function for del'ing, an attribute. Typical use is to define a managed attribute *x*:

```
class C(object):
    def __init__(self):
        self._x = None

    def getx(self):
        return self._x
    def setx(self, value):
        self._x = value
    def delx(self):
        del self._x
x = property(getx, setx, delx, "I'm the 'x' property.")
```

If then *c* is an instance of *C*, *c.x* will invoke the getter, *c.x = value* will invoke the setter and *del c.x* the deleter.

If given, *doc* will be the docstring of the property attribute. Otherwise, the property will copy *fget*'s docstring (if it exists). This makes it possible to create read-only properties easily using `property()` as a *decorator*:

```
class Parrot(object):
    def __init__(self):
        self._voltage = 100000

    @property
    def voltage(self):
        """Get the current voltage."""
        return self._voltage
```

turns the `voltage()` method into a “getter” for a read-only attribute with the same name.

A property object has `getter`, `setter`, and `deleter` methods usable as decorators that create a copy of the property with the corresponding accessor function set to the decorated function. This is best explained with an example:

```
class C(object):
    def __init__(self):
        self._x = None

    @property
    def x(self):
        """I'm the 'x' property."""
        return self._x

    @x.setter
    def x(self, value):
        self._x = value

    @x.deleter
    def x(self):
        del self._x
```

This code is exactly equivalent to the first example. Be sure to give the additional functions the same name as the original property (*x* in this case.)

The returned property also has the attributes `fget`, `fset`, and `fdel` corresponding to the constructor arguments. New in version 2.2.Changed in version 2.5: Use *fget*'s docstring if no *doc* given.Changed in version 2.6: The `getter`, `setter`, and `deleter` attributes were added.

**range** (*stop*)

**range** (*start*, *stop* [, *step* ])

This is a versatile function to create lists containing arithmetic progressions. It is most often used in `for` loops. The arguments must be plain integers. If the *step* argument is omitted, it defaults to 1. If the *start* argument is omitted, it defaults to 0. The full form returns a list of plain integers [*start*, *start* + *step*, *start* + 2 \* *step*, ...]. If *step* is positive, the last element is the largest *start* + *i* \* *step* less than *stop*; if *step* is negative, the last element is the smallest *start* + *i* \* *step* greater than *stop*. *step* must not be zero (or else `ValueError` is raised). Example:

```
>>> range(10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

```

>>> range(1, 11)
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
>>> range(0, 30, 5)
[0, 5, 10, 15, 20, 25]
>>> range(0, 10, 3)
[0, 3, 6, 9]
>>> range(0, -10, -1)
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]
>>> range(0)
[]
>>> range(1, 0)
[]

```

**raw\_input** (*[prompt]*)

If the *prompt* argument is present, it is written to standard output without a trailing newline. The function then reads a line from input, converts it to a string (stripping a trailing newline), and returns that. When EOF is read, `EOFError` is raised. Example:

```

>>> s = raw_input('--> ')
--> Monty Python's Flying Circus
>>> s
"Monty Python's Flying Circus"

```

If the `readline` module was loaded, then `raw_input()` will use it to provide elaborate line editing and history features.

**reduce** (*function, iterable* [*, initializer* ])

Apply *function* of two arguments cumulatively to the items of *iterable*, from left to right, so as to reduce the iterable to a single value. For example, `reduce(lambda x, y: x+y, [1, 2, 3, 4, 5])` calculates `(( (1+2)+3)+4)+5`. The left argument, *x*, is the accumulated value and the right argument, *y*, is the update value from the *iterable*. If the optional *initializer* is present, it is placed before the items of the iterable in the calculation, and serves as a default when the iterable is empty. If *initializer* is not given and *iterable* contains only one item, the first item is returned. Roughly equivalent to:

```

def reduce(function, iterable, initializer=None):
    it = iter(iterable)
    if initializer is None:
        try:
            initializer = next(it)
        except StopIteration:
            raise TypeError('reduce() of empty sequence with no initial value')
    accum_value = initializer
    for x in iterable:
        accum_value = function(accum_value, x)
    return accum_value

```

**reload** (*module*)

Reload a previously imported *module*. The argument must be a module object, so it must have been successfully imported before. This is useful if you have edited the module source file using an external editor and want to try out the new version without leaving the Python interpreter. The return value is the module object (the same as the *module* argument).

When `reload(module)` is executed:

- Python modules' code is recompiled and the module-level code reexecuted, defining a new set of objects which are bound to names in the module's dictionary. The `init` function of extension modules is not called a second time.
- As with all other objects in Python the old objects are only reclaimed after their reference counts drop to zero.
- The names in the module namespace are updated to point to any new or changed objects.
- Other references to the old objects (such as names external to the module) are not rebound to refer to the new objects and must be updated in each namespace where they occur if that is desired.

There are a number of other caveats:

If a module is syntactically correct but its initialization fails, the first `import` statement for it does not bind its name locally, but does store a (partially initialized) module object in `sys.modules`. To reload the module you must first `import` it again (this will bind the name to the partially initialized module object) before you can `reload()` it.

When a module is reloaded, its dictionary (containing the module's global variables) is retained. Redefinitions of names will override the old definitions, so this is generally not a problem. If the new version of a module does not define a name that was defined by the old version, the old definition remains. This feature can be used to the module's advantage if it maintains a global table or cache of objects — with a `try` statement it can test for the table's presence and skip its initialization if desired:

```
try:
    cache
except NameError:
    cache = {}
```

It is legal though generally not very useful to reload built-in or dynamically loaded modules, except for `sys`, `__main__` and `__builtin__`. In many cases, however, extension modules are not designed to be initialized more than once, and may fail in arbitrary ways when reloaded.

If a module imports objects from another module using `from ... import ...`, calling `reload()` for the other module does not redefine the objects imported from it — one way around this is to re-execute the `from` statement, another is to use `import` and qualified names (`module.*name*`) instead.

If a module instantiates instances of a class, reloading the module that defines the class does not affect the method definitions of the instances — they continue to use the old class definition. The same is true for derived classes.

### **repr** (*object*)

Return a string containing a printable representation of an object. This is the same value yielded by conversions (reverse quotes). It is sometimes useful to be able to access this operation as an ordinary function. For many types, this function makes an attempt to return a string that would yield an object with the same value when passed to `eval()`, otherwise the representation is a string enclosed in angle brackets that contains the name of the type of the object together with additional information often including the name and address of the object. A class can control what this function returns for its instances by defining a `__repr__()` method.

### **reversed** (*seq*)

Return a reverse *iterator*. *seq* must be an object which has a `__reversed__()` method or supports the sequence protocol (the `__len__()` method and the `__getitem__()` method with integer arguments starting at 0). New in version 2.4. Changed in version 2.6: Added the possibility to write a custom `__reversed__()` method.

### **round** (*number* [, *ndigits* ])

Return the floating point value *number* rounded to *ndigits* digits after the decimal point. If *ndigits* is omitted, it defaults to zero. The result is a floating point number. Values are rounded to the closest multiple of 10 to

the power minus *ndigits*; if two multiples are equally close, rounding is done away from 0 (so. for example, `round(0.5)` is 1.0 and `round(-0.5)` is -1.0).

---

**Note:** The behavior of `round()` for floats can be surprising: for example, `round(2.675, 2)` gives 2.67 instead of the expected 2.68. This is not a bug: it's a result of the fact that most decimal fractions can't be represented exactly as a float. See *tut-fp-issues* for more information.

---

**set** (*[iterable]*)

Return a new set, optionally with elements taken from *iterable*. The set type is described in *Set Types — set, frozenset*.

For other containers see the built in `dict`, `list`, and `tuple` classes, and the `collections` module. New in version 2.4.

**setattr** (*object, name, value*)

This is the counterpart of `getattr()`. The arguments are an object, a string and an arbitrary value. The string may name an existing attribute or a new attribute. The function assigns the value to the attribute, provided the object allows it. For example, `setattr(x, 'foobar', 123)` is equivalent to `x.foobar = 123`.

**slice** (*stop*)

**slice** (*start, stop[, step]*)

Return a *slice* object representing the set of indices specified by `range(start, stop, step)`. The *start* and *step* arguments default to `None`. Slice objects have read-only data attributes `start`, `stop` and `step` which merely return the argument values (or their default). They have no other explicit functionality; however they are used by Numerical Python and other third party extensions. Slice objects are also generated when extended indexing syntax is used. For example: `a[start:stop:step]` or `a[start:stop, i]`. See `itertools.islice()` for an alternate version that returns an iterator.

**sorted** (*iterable[, cmp[, key[, reverse]]]*)

Return a new sorted list from the items in *iterable*.

The optional arguments *cmp*, *key*, and *reverse* have the same meaning as those for the `list.sort()` method (described in section *Mutable Sequence Types*).

*cmp* specifies a custom comparison function of two arguments (iterable elements) which should return a negative, zero or positive number depending on whether the first argument is considered smaller than, equal to, or larger than the second argument: `cmp=lambda x,y: cmp(x.lower(), y.lower())`. The default value is `None`.

*key* specifies a function of one argument that is used to extract a comparison key from each list element: `key=str.lower`. The default value is `None` (compare the elements directly).

*reverse* is a boolean value. If set to `True`, then the list elements are sorted as if each comparison were reversed.

In general, the *key* and *reverse* conversion processes are much faster than specifying an equivalent *cmp* function. This is because *cmp* is called multiple times for each list element while *key* and *reverse* touch each element only once. Use `functools.cmp_to_key()` to convert an old-style *cmp* function to a *key* function.

For sorting examples and a brief sorting tutorial, see *Sorting HowTo*. New in version 2.4.

**staticmethod** (*function*)

Return a static method for *function*.

A static method does not receive an implicit first argument. To declare a static method, use this idiom:

```
class C:
    @staticmethod
    def f(arg1, arg2, ...): ...
```

The `@staticmethod` form is a function *decorator* – see the description of function definitions in *function* for details.

It can be called either on the class (such as `C.f()`) or on an instance (such as `C().f()`). The instance is ignored except for its class.

Static methods in Python are similar to those found in Java or C++. Also see `classmethod()` for a variant that is useful for creating alternate class constructors.

For more information on static methods, consult the documentation on the standard type hierarchy in *types*. New in version 2.2.Changed in version 2.4: Function decorator syntax added.

**str**(*[object]*)

Return a string containing a nicely printable representation of an object. For strings, this returns the string itself. The difference with `repr(object)` is that `str(object)` does not always attempt to return a string that is acceptable to `eval()`; its goal is to return a printable string. If no argument is given, returns the empty string, "".

For more information on strings see *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange* which describes sequence functionality (strings are sequences), and also the string-specific methods described in the *String Methods* section. To output formatted strings use template strings or the `%` operator described in the *String Formatting Operations* section. In addition see the *String Services* section. See also `unicode()`.

**sum**(*iterable*[, *start*])

Sums *start* and the items of an *iterable* from left to right and returns the total. *start* defaults to 0. The *iterable*'s items are normally numbers, and the start value is not allowed to be a string.

For some use cases, there are good alternatives to `sum()`. The preferred, fast way to concatenate a sequence of strings is by calling `".join(sequence)`. To add floating point values with extended precision, see `math.fsum()`. To concatenate a series of iterables, consider using `itertools.chain()`. New in version 2.3.

**super**(*type*[, *object-or-type*])

Return a proxy object that delegates method calls to a parent or sibling class of *type*. This is useful for accessing inherited methods that have been overridden in a class. The search order is same as that used by `getattr()` except that the *type* itself is skipped.

The `__mro__` attribute of the *type* lists the method resolution search order used by both `getattr()` and `super()`. The attribute is dynamic and can change whenever the inheritance hierarchy is updated.

If the second argument is omitted, the `super` object returned is unbound. If the second argument is an object, `isinstance(obj, type)` must be true. If the second argument is a type, `issubclass(type2, type)` must be true (this is useful for classmethods).

---

**Note:** `super()` only works for *new-style classes*.

---

There are two typical use cases for *super*. In a class hierarchy with single inheritance, *super* can be used to refer to parent classes without naming them explicitly, thus making the code more maintainable. This use closely parallels the use of *super* in other programming languages.

The second use case is to support cooperative multiple inheritance in a dynamic execution environment. This use case is unique to Python and is not found in statically compiled languages or languages that only support single inheritance. This makes it possible to implement “diamond diagrams” where multiple base classes implement the same method. Good design dictates that this method have the same calling signature in every case (because the order of calls is determined at runtime, because that order adapts to changes in the class hierarchy, and because that order can include sibling classes that are unknown prior to runtime).

For both use cases, a typical superclass call looks like this:

```
class C(B):
    def method(self, arg):
        super(C, self).method(arg)
```

Note that `super()` is implemented as part of the binding process for explicit dotted attribute lookups such as `super().__getitem__(name)`. It does so by implementing its own `__getattr__()` method for searching classes in a predictable order that supports cooperative multiple inheritance. Accordingly, `super()` is undefined for implicit lookups using statements or operators such as `super()[name]`.

Also note that `super()` is not limited to use inside methods. The two argument form specifies the arguments exactly and makes the appropriate references.

For practical suggestions on how to design cooperative classes using `super()`, see [guide to using super\(\)](#). New in version 2.2.

**tuple** (*[iterable]*)

Return a tuple whose items are the same and in the same order as *iterable*'s items. *iterable* may be a sequence, a container that supports iteration, or an iterator object. If *iterable* is already a tuple, it is returned unchanged. For instance, `tuple('abc')` returns `('a', 'b', 'c')` and `tuple([1, 2, 3])` returns `(1, 2, 3)`. If no argument is given, returns a new empty tuple, `()`.

`tuple` is an immutable sequence type, as documented in *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange*. For other containers see the built in `dict`, `list`, and `set` classes, and the `collections` module.

**type** (*object*)

Return the type of an *object*. The return value is a type object. The `isinstance()` built-in function is recommended for testing the type of an object.

With three arguments, `type()` functions as a constructor as detailed below.

**type** (*name, bases, dict*)

Return a new type object. This is essentially a dynamic form of the `class` statement. The *name* string is the class name and becomes the `__name__` attribute; the *bases* tuple itemizes the base classes and becomes the `__bases__` attribute; and the *dict* dictionary is the namespace containing definitions for class body and becomes the `__dict__` attribute. For example, the following two statements create identical `type` objects:

```
>>> class X(object):
...     a = 1
...
>>> X = type('X', (object,), dict(a=1))
```

New in version 2.2.

**unichr** (*i*)

Return the Unicode string of one character whose Unicode code is the integer *i*. For example, `unichr(97)` returns the string `u'a'`. This is the inverse of `ord()` for Unicode strings. The valid range for the argument depends how Python was configured – it may be either UCS2 `[0..0xFFFF]` or UCS4 `[0..0x10FFFF]`. `ValueError` is raised otherwise. For ASCII and 8-bit strings see `chr()`. New in version 2.0.

**unicode** (*[object[, encoding[, errors]]]*)

Return the Unicode string version of *object* using one of the following modes:

If *encoding* and/or *errors* are given, `unicode()` will decode the object which can either be an 8-bit string or a character buffer using the codec for *encoding*. The *encoding* parameter is a string giving the name of an encoding; if the encoding is not known, `LookupError` is raised. Error handling is done according to *errors*; this specifies the treatment of characters which are invalid in the input encoding. If *errors* is `'strict'` (the default), a `ValueError` is raised on errors, while a value of `'ignore'` causes errors to be silently ignored,

and a value of `'replace'` causes the official Unicode replacement character, U+FFFD, to be used to replace input characters which cannot be decoded. See also the `codecs` module.

If no optional parameters are given, `unicode()` will mimic the behaviour of `str()` except that it returns Unicode strings instead of 8-bit strings. More precisely, if *object* is a Unicode string or subclass it will return that Unicode string without any additional decoding applied.

For objects which provide a `__unicode__()` method, it will call this method without arguments to create a Unicode string. For all other objects, the 8-bit string version or representation is requested and then converted to a Unicode string using the codec for the default encoding in `'strict'` mode.

For more information on Unicode strings see *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange* which describes sequence functionality (Unicode strings are sequences), and also the string-specific methods described in the *String Methods* section. To output formatted strings use template strings or the `%` operator described in the *String Formatting Operations* section. In addition see the *String Services* section. See also `str()`. New in version 2.0.Changed in version 2.2: Support for `__unicode__()` added.

**vars** (*[object]*)

Return the `__dict__` attribute for a module, class, instance, or any other object with a `__dict__` attribute.

Objects such as modules and instances have an updateable `__dict__` attribute; however, other objects may have write restrictions on their `__dict__` attributes (for example, new-style classes use a dictproxy to prevent direct dictionary updates).

Without an argument, `vars()` acts like `locals()`. Note, the locals dictionary is only useful for reads since updates to the locals dictionary are ignored.

**xrange** (*stop*)

**xrange** (*start, stop* [*, step* ])

This function is very similar to `range()`, but returns an “xrange object” instead of a list. This is an opaque sequence type which yields the same values as the corresponding list, without actually storing them all simultaneously. The advantage of `xrange()` over `range()` is minimal (since `xrange()` still has to create the values when asked for them) except when a very large range is used on a memory-starved machine or when all of the range’s elements are never used (such as when the loop is usually terminated with `break`).

**CPython implementation detail:** `xrange()` is intended to be simple and fast. Implementations may impose restrictions to achieve this. The C implementation of Python restricts all arguments to native C longs (“short” Python integers), and also requires that the number of elements fit in a native C long. If a larger range is needed, an alternate version can be crafted using the `itertools` module: `islice(count(start, step), (stop-start+step-1+2*(step<0))//step)`.

**zip** (*[iterable, ...]*)

This function returns a list of tuples, where the *i*-th tuple contains the *i*-th element from each of the argument sequences or iterables. The returned list is truncated in length to the length of the shortest argument sequence. When there are multiple arguments which are all of the same length, `zip()` is similar to `map()` with an initial argument of `None`. With a single sequence argument, it returns a list of 1-tuples. With no arguments, it returns an empty list.

The left-to-right evaluation order of the iterables is guaranteed. This makes possible an idiom for clustering a data series into n-length groups using `zip(*[iter(s)]*n)`.

`zip()` in conjunction with the `*` operator can be used to unzip a list:

```
>>> x = [1, 2, 3]
>>> y = [4, 5, 6]
>>> zipped = zip(x, y)
>>> zipped
[(1, 4), (2, 5), (3, 6)]
>>> x2, y2 = zip(*zipped)
```

```
>>> x == list(x2) and y == list(y2)
True
```

New in version 2.0.Changed in version 2.4: Formerly, `zip()` required at least one argument and `zip()` raised a `TypeError` instead of returning an empty list.

```
__import__(name[, globals[, locals[, fromlist[, level]]]])
```

---

**Note:** This is an advanced function that is not needed in everyday Python programming, unlike `importlib.import_module()`.

---

This function is invoked by the `import` statement. It can be replaced (by importing the `__builtin__` module and assigning to `__builtin__.__import__`) in order to change semantics of the `import` statement, but nowadays it is usually simpler to use import hooks (see [PEP 302](#)). Direct use of `__import__()` is rare, except in cases where you want to import a module whose name is only known at runtime.

The function imports the module *name*, potentially using the given *globals* and *locals* to determine how to interpret the name in a package context. The *fromlist* gives the names of objects or submodules that should be imported from the module given by *name*. The standard implementation does not use its *locals* argument at all, and uses its *globals* only to determine the package context of the `import` statement.

*level* specifies whether to use absolute or relative imports. The default is `-1` which indicates both absolute and relative imports will be attempted. `0` means only perform absolute imports. Positive values for *level* indicate the number of parent directories to search relative to the directory of the module calling `__import__()`.

When the *name* variable is of the form `package.module`, normally, the top-level package (the name up till the first dot) is returned, *not* the module named by *name*. However, when a non-empty *fromlist* argument is given, the module named by *name* is returned.

For example, the statement `import spam` results in bytecode resembling the following code:

```
spam = __import__('spam', globals(), locals(), [], -1)
```

The statement `import spam.ham` results in this call:

```
spam = __import__('spam.ham', globals(), locals(), [], -1)
```

Note how `__import__()` returns the toplevel module here because this is the object that is bound to a name by the `import` statement.

On the other hand, the statement `from spam.ham import eggs, sausage as saus` results in

```
_temp = __import__('spam.ham', globals(), locals(), ['eggs', 'sausage'], -1)
eggs = _temp.eggs
saus = _temp.sausage
```

Here, the `spam.ham` module is returned from `__import__()`. From this object, the names to import are retrieved and assigned to their respective names.

If you simply want to import a module (potentially within a package) by name, use `importlib.import_module()`. Changed in version 2.5: The *level* parameter was added.Changed in version 2.5: Keyword support for parameters was added.



# NON-ESSENTIAL BUILT-IN FUNCTIONS

There are several built-in functions that are no longer essential to learn, know or use in modern Python programming. They have been kept here to maintain backwards compatibility with programs written for older versions of Python.

Python programmers, trainers, students and book writers should feel free to bypass these functions without concerns about missing something important.

**apply** (*function*, *args*[, *keywords* ])

The *function* argument must be a callable object (a user-defined or built-in function or method, or a class object) and the *args* argument must be a sequence. The *function* is called with *args* as the argument list; the number of arguments is the length of the tuple. If the optional *keywords* argument is present, it must be a dictionary whose keys are strings. It specifies keyword arguments to be added to the end of the argument list. Calling `apply()` is different from just calling `function(args)`, since in that case there is always exactly one argument. The use of `apply()` is equivalent to `function(*args, **keywords)`. Deprecated since version 2.3: Use the extended call syntax with `*args` and `**keywords` instead.

**buffer** (*object*[, *offset*[, *size* ] ])

The *object* argument must be an object that supports the buffer call interface (such as strings, arrays, and buffers). A new buffer object will be created which references the *object* argument. The buffer object will be a slice from the beginning of *object* (or from the specified *offset*). The slice will extend to the end of *object* (or will have a length given by the *size* argument).

**coerce** (*x*, *y*)

Return a tuple consisting of the two numeric arguments converted to a common type, using the same rules as used by arithmetic operations. If coercion is not possible, raise `TypeError`.

**intern** (*string*)

Enter *string* in the table of “interned” strings and return the interned string – which is *string* itself or a copy. Interning strings is useful to gain a little performance on dictionary lookup – if the keys in a dictionary are interned, and the lookup key is interned, the key comparisons (after hashing) can be done by a pointer compare instead of a string compare. Normally, the names used in Python programs are automatically interned, and the dictionaries used to hold module, class or instance attributes have interned keys. Changed in version 2.3: Interned strings are not immortal (like they used to be in Python 2.2 and before); you must keep a reference to the return value of `intern()` around to benefit from it.



# BUILT-IN CONSTANTS

A small number of constants live in the built-in namespace. They are:

**False**

The false value of the `bool` type. New in version 2.3.

**True**

The true value of the `bool` type. New in version 2.3.

**None**

The sole value of `types.NoneType`. `None` is frequently used to represent the absence of a value, as when default arguments are not passed to a function. Changed in version 2.4: Assignments to `None` are illegal and raise a `SyntaxError`.

**NotImplemented**

Special value which can be returned by the “rich comparison” special methods (`__eq__()`, `__lt__()`, and friends), to indicate that the comparison is not implemented with respect to the other type.

**Ellipsis**

Special value used in conjunction with extended slicing syntax.

**`__debug__`**

This constant is true if Python was not started with an `-O` option. See also the `assert` statement.

---

**Note:** The names `None` and `__debug__` cannot be reassigned (assignments to them, even as an attribute name, raise `SyntaxError`), so they can be considered “true” constants. Changed in version 2.7: Assignments to `__debug__` as an attribute became illegal.

---

## 4.1 Constants added by the `site` module

The `site` module (which is imported automatically during startup, except if the `-S` command-line option is given) adds several constants to the built-in namespace. They are useful for the interactive interpreter shell and should not be used in programs.

**`quit`** (`[code=None]`)  
**`exit`** (`[code=None]`)

Objects that when printed, print a message like “Use `quit()` or Ctrl-D (i.e. EOF) to exit”, and when called, raise `SystemExit` with the specified exit code.

**`copyright`**  
**`license`**

**credits**

Objects that when printed, print a message like “Type license() to see the full license text”, and when called, display the corresponding text in a pager-like fashion (one screen at a time).

# BUILT-IN TYPES

The following sections describe the standard types that are built into the interpreter.

---

**Note:** Historically (until release 2.2), Python’s built-in types have differed from user-defined types because it was not possible to use the built-in types as the basis for object-oriented inheritance. This limitation no longer exists.

---

The principal built-in types are numerics, sequences, mappings, files, classes, instances and exceptions.

Some operations are supported by several object types; in particular, practically all objects can be compared, tested for truth value, and converted to a string (with the `repr()` function or the slightly different `str()` function). The latter function is implicitly used when an object is written by the `print()` function.

## 5.1 Truth Value Testing

Any object can be tested for truth value, for use in an `if` or `while` condition or as operand of the Boolean operations below. The following values are considered false:

- `None`
- `False`
- zero of any numeric type, for example, `0`, `0L`, `0.0`, `0j`.
- any empty sequence, for example, `''`, `()`, `[]`.
- any empty mapping, for example, `{}`.
- instances of user-defined classes, if the class defines a `__nonzero__()` or `__len__()` method, when that method returns the integer zero or `bool` value `False`.<sup>1</sup>

All other values are considered true — so objects of many types are always true.

Operations and built-in functions that have a Boolean result always return `0` or `False` for false and `1` or `True` for true, unless otherwise stated. (Important exception: the Boolean operations `or` and `and` always return one of their operands.)

---

<sup>1</sup> Additional information on these special methods may be found in the Python Reference Manual (*customization*).

## 5.2 Boolean Operations — and, or, not

These are the Boolean operations, ordered by ascending priority:

Operation	Result	Notes
<code>x or y</code>	if <code>x</code> is false, then <code>y</code> , else <code>x</code>	(1)
<code>x and y</code>	if <code>x</code> is false, then <code>x</code> , else <code>y</code>	(2)
<code>not x</code>	if <code>x</code> is false, then <code>True</code> , else <code>False</code>	(3)

Notes:

1. This is a short-circuit operator, so it only evaluates the second argument if the first one is `False`.
2. This is a short-circuit operator, so it only evaluates the second argument if the first one is `True`.
3. `not` has a lower priority than non-Boolean operators, so `not a == b` is interpreted as `not (a == b)`, and `a == not b` is a syntax error.

## 5.3 Comparisons

Comparison operations are supported by all objects. They all have the same priority (which is higher than that of the Boolean operations). Comparisons can be chained arbitrarily; for example, `x < y <= z` is equivalent to `x < y` and `y <= z`, except that `y` is evaluated only once (but in both cases `z` is not evaluated at all when `x < y` is found to be false).

This table summarizes the comparison operations:

Operation	Meaning	Notes
<code>&lt;</code>	strictly less than	
<code>&lt;=</code>	less than or equal	
<code>&gt;</code>	strictly greater than	
<code>&gt;=</code>	greater than or equal	
<code>==</code>	equal	
<code>!=</code>	not equal	(1)
<code>is</code>	object identity	
<code>is not</code>	negated object identity	

Notes:

1. `!=` can also be written `<>`, but this is an obsolete usage kept for backwards compatibility only. New code should always use `!=`.

Objects of different types, except different numeric types and different string types, never compare equal; such objects are ordered consistently but arbitrarily (so that sorting a heterogeneous array yields a consistent result). Furthermore, some types (for example, file objects) support only a degenerate notion of comparison where any two objects of that type are unequal. Again, such objects are ordered arbitrarily but consistently. The `<`, `<=`, `>` and `>=` operators will raise a `TypeError` exception when any operand is a complex number.

Instances of a class normally compare as non-equal unless the class defines the `__cmp__()` method. Refer to *customization*) for information on the use of this method to effect object comparisons.

**CPython implementation detail:** Objects of different types except numbers are ordered by their type names; objects of the same types that don't support proper comparison are ordered by their address.

Two more operations with the same syntactic priority, `in` and `not in`, are supported only by sequence types (below).

## 5.4 Numeric Types — int, float, long, complex

There are four distinct numeric types: *plain integers*, *long integers*, *floating point numbers*, and *complex numbers*. In addition, Booleans are a subtype of plain integers. Plain integers (also just called *integers*) are implemented using `long` in C, which gives them at least 32 bits of precision (`sys.maxint` is always set to the maximum plain integer value for the current platform, the minimum value is `-sys.maxint - 1`). Long integers have unlimited precision. Floating point numbers are usually implemented using `double` in C; information about the precision and internal representation of floating point numbers for the machine on which your program is running is available in `sys.float_info`. Complex numbers have a real and imaginary part, which are each a floating point number. To extract these parts from a complex number `z`, use `z.real` and `z.imag`. (The standard library includes additional numeric types, `fractions` that hold rationals, and `decimal` that hold floating-point numbers with user-definable precision.)

Numbers are created by numeric literals or as the result of built-in functions and operators. Unadorned integer literals (including binary, hex, and octal numbers) yield plain integers unless the value they denote is too large to be represented as a plain integer, in which case they yield a long integer. Integer literals with an `'L'` or `'l'` suffix yield long integers (`'L'` is preferred because `11` looks too much like eleven!). Numeric literals containing a decimal point or an exponent sign yield floating point numbers. Appending `'j'` or `'J'` to a numeric literal yields a complex number with a zero real part. A complex numeric literal is the sum of a real and an imaginary part.

Python fully supports mixed arithmetic: when a binary arithmetic operator has operands of different numeric types, the operand with the “narrower” type is widened to that of the other, where plain integer is narrower than long integer is narrower than floating point is narrower than complex. Comparisons between numbers of mixed type use the same rule.<sup>2</sup> The constructors `int()`, `long()`, `float()`, and `complex()` can be used to produce numbers of a specific type.

All built-in numeric types support the following operations. See *power* and later sections for the operators’ priorities.

Operation	Result	Notes
<code>x + y</code>	sum of <i>x</i> and <i>y</i>	
<code>x - y</code>	difference of <i>x</i> and <i>y</i>	
<code>x * y</code>	product of <i>x</i> and <i>y</i>	
<code>x / y</code>	quotient of <i>x</i> and <i>y</i>	(1)
<code>x // y</code>	(floored) quotient of <i>x</i> and <i>y</i>	(4)(5)
<code>x % y</code>	remainder of <i>x</i> / <i>y</i>	(4)
<code>-x</code>	<i>x</i> negated	
<code>+x</code>	<i>x</i> unchanged	
<code>abs(x)</code>	absolute value or magnitude of <i>x</i>	(3)
<code>int(x)</code>	<i>x</i> converted to integer	(2)
<code>long(x)</code>	<i>x</i> converted to long integer	(2)
<code>float(x)</code>	<i>x</i> converted to floating point	(6)
<code>complex(re, im)</code>	a complex number with real part <i>re</i> , imaginary part <i>im</i> . <i>im</i> defaults to zero.	
<code>c.conjugate()</code>	conjugate of the complex number <i>c</i> . (Identity on real numbers)	
<code>divmod(x, y)</code>	the pair ( <code>x // y</code> , <code>x % y</code> )	(3)(4)
<code>pow(x, y)</code>	<i>x</i> to the power <i>y</i>	(3)(7)
<code>x ** y</code>	<i>x</i> to the power <i>y</i>	(7)

Notes:

- For (plain or long) integer division, the result is an integer. The result is always rounded towards minus infinity: `1/2` is 0, `(-1)/2` is -1, `1/(-2)` is -1, and `(-1)/(-2)` is 0. Note that the result is a long integer if either operand is a long integer, regardless of the numeric value.
- Conversion from floats using `int()` or `long()` truncates toward zero like the related function,

<sup>2</sup> As a consequence, the list `[1, 2]` is considered equal to `[1.0, 2.0]`, and similarly for tuples.

`math.trunc()`. Use the function `math.floor()` to round downward and `math.ceil()` to round upward.

3. See *Built-in Functions* for a full description.
4. Deprecated since version 2.3: The floor division operator, the modulo operator, and the `divmod()` function are no longer defined for complex numbers. Instead, convert to a floating point number using the `abs()` function if appropriate.
5. Also referred to as integer division. The resultant value is a whole integer, though the result's type is not necessarily int.
6. float also accepts the strings "nan" and "inf" with an optional prefix "+" or "-" for Not a Number (NaN) and positive or negative infinity. New in version 2.6.
7. Python defines `pow(0, 0)` and `0 ** 0` to be 1, as is common for programming languages.

All `numbers.Real` types (`int`, `long`, and `float`) also include the following operations:

Operation	Result	Notes
<code>math.trunc(x)</code>	$x$ truncated to Integral	
<code>round(x[, n])</code>	$x$ rounded to $n$ digits, rounding half to even. If $n$ is omitted, it defaults to 0.	
<code>math.floor(x)</code>	the greatest integral float $\leq x$	
<code>math.ceil(x)</code>	the least integral float $\geq x$	

### 5.4.1 Bitwise Operations on Integer Types

Bitwise operations only make sense for integers. Negative numbers are treated as their 2's complement value (this assumes a sufficiently large number of bits that no overflow occurs during the operation).

The priorities of the binary bitwise operations are all lower than the numeric operations and higher than the comparisons; the unary operation `~` has the same priority as the other unary numeric operations (`+` and `-`).

This table lists the bitwise operations sorted in ascending priority (operations in the same box have the same priority):

Operation	Result	Notes
<code>x   y</code>	bitwise <i>or</i> of $x$ and $y$	
<code>x ^ y</code>	bitwise <i>exclusive or</i> of $x$ and $y$	
<code>x &amp; y</code>	bitwise <i>and</i> of $x$ and $y$	
<code>x &lt;&lt; n</code>	$x$ shifted left by $n$ bits	(1)(2)
<code>x &gt;&gt; n</code>	$x$ shifted right by $n$ bits	(1)(3)
<code>~x</code>	the bits of $x$ inverted	

Notes:

1. Negative shift counts are illegal and cause a `ValueError` to be raised.
2. A left shift by  $n$  bits is equivalent to multiplication by `pow(2, n)`. A long integer is returned if the result exceeds the range of plain integers.
3. A right shift by  $n$  bits is equivalent to division by `pow(2, n)`.

### 5.4.2 Additional Methods on Integer Types

The integer types implement the `numbers.Integral` *abstract base class*. In addition, they provide one more method:

`int.bit_length()`

`long.bit_length()`

Return the number of bits necessary to represent an integer in binary, excluding the sign and leading zeros:

```
>>> n = -37
>>> bin(n)
'-0b100101'
>>> n.bit_length()
6
```

More precisely, if  $x$  is nonzero, then `x.bit_length()` is the unique positive integer  $k$  such that  $2^{k-1} \leq \text{abs}(x) < 2^k$ . Equivalently, when  $\text{abs}(x)$  is small enough to have a correctly rounded logarithm, then  $k = 1 + \text{int}(\log(\text{abs}(x), 2))$ . If  $x$  is zero, then `x.bit_length()` returns 0.

Equivalent to:

```
def bit_length(self):
    s = bin(self)          # binary representation: bin(-37) --> '-0b100101'
    s = s.lstrip('-0b')   # remove leading zeros and minus sign
    return len(s)         # len('100101') --> 6
```

New in version 2.7.

### 5.4.3 Additional Methods on Float

The float type implements the `numbers.Real` abstract base class. float also has the following additional methods.

`float.as_integer_ratio()`

Return a pair of integers whose ratio is exactly equal to the original float and with a positive denominator. Raises `OverflowError` on infinities and a `ValueError` on NaNs. New in version 2.6.

`float.is_integer()`

Return True if the float instance is finite with integral value, and False otherwise:

```
>>> (-2.0).is_integer()
True
>>> (3.2).is_integer()
False
```

New in version 2.6.

Two methods support conversion to and from hexadecimal strings. Since Python's floats are stored internally as binary numbers, converting a float to or from a *decimal* string usually involves a small rounding error. In contrast, hexadecimal strings allow exact representation and specification of floating-point numbers. This can be useful when debugging, and in numerical work.

`float.hex()`

Return a representation of a floating-point number as a hexadecimal string. For finite floating-point numbers, this representation will always include a leading 0x and a trailing p and exponent. New in version 2.6.

`float.fromhex(s)`

Class method to return the float represented by a hexadecimal string *s*. The string *s* may have leading and trailing whitespace. New in version 2.6.

Note that `float.hex()` is an instance method, while `float.fromhex()` is a class method.

A hexadecimal string takes the form:

```
[sign] ['0x'] integer ['.' fraction] ['p' exponent]
```

where the optional `sign` may be either `+` or `-`, `integer` and `fraction` are strings of hexadecimal digits, and `exponent` is a decimal integer with an optional leading sign. Case is not significant, and there must be at least one hexadecimal digit in either the integer or the fraction. This syntax is similar to the syntax specified in section 6.4.4.2 of the C99 standard, and also to the syntax used in Java 1.5 onwards. In particular, the output of `float.hex()` is usable as a hexadecimal floating-point literal in C or Java code, and hexadecimal strings produced by C's `%a` format character or Java's `Double.toHexString` are accepted by `float.fromhex()`.

Note that the exponent is written in decimal rather than hexadecimal, and that it gives the power of 2 by which to multiply the coefficient. For example, the hexadecimal string `0x3.a7p10` represents the floating-point number  $(3 + 10./16 + 7./16**2) * 2.0**10$ , or `3740.0`:

```
>>> float.fromhex('0x3.a7p10')
3740.0
```

Applying the reverse conversion to `3740.0` gives a different hexadecimal string representing the same number:

```
>>> float.hex(3740.0)
'0x1.d380000000000p+11'
```

## 5.5 Iterator Types

New in version 2.2. Python supports a concept of iteration over containers. This is implemented using two distinct methods; these are used to allow user-defined classes to support iteration. Sequences, described below in more detail, always support the iteration methods.

One method needs to be defined for container objects to provide iteration support:

```
container.__iter__()
```

Return an iterator object. The object is required to support the iterator protocol described below. If a container supports different types of iteration, additional methods can be provided to specifically request iterators for those iteration types. (An example of an object supporting multiple forms of iteration would be a tree structure which supports both breadth-first and depth-first traversal.) This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

The iterator objects themselves are required to support the following two methods, which together form the *iterator protocol*:

```
iterator.__iter__()
```

Return the iterator object itself. This is required to allow both containers and iterators to be used with the `for` and `in` statements. This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

```
iterator.next()
```

Return the next item from the container. If there are no further items, raise the `StopIteration` exception. This method corresponds to the `tp_iternext` slot of the type structure for Python objects in the Python/C API.

Python defines several iterator objects to support iteration over general and specific sequence types, dictionaries, and other more specialized forms. The specific types are not important beyond their implementation of the iterator protocol.

The intention of the protocol is that once an iterator's `next()` method raises `StopIteration`, it will continue to do so on subsequent calls. Implementations that do not obey this property are deemed broken. (This constraint was added in Python 2.3; in Python 2.2, various iterators are broken according to this rule.)

## 5.5.1 Generator Types

Python's *generators* provide a convenient way to implement the iterator protocol. If a container object's `__iter__()` method is implemented as a generator, it will automatically return an iterator object (technically, a generator object) supplying the `__iter__()` and `next()` methods. More information about generators can be found in *the documentation for the yield expression*.

## 5.6 Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange

There are seven sequence types: strings, Unicode strings, lists, tuples, bytearrays, buffers, and xrange objects.

For other containers see the built in `dict` and `set` classes, and the `collections` module.

String literals are written in single or double quotes: `'xyzzzy'`, `"frobozz"`. See *strings* for more about string literals. Unicode strings are much like strings, but are specified in the syntax using a preceding `'u'` character: `u'abc'`, `u"def"`. In addition to the functionality described here, there are also string-specific methods described in the *String Methods* section. Lists are constructed with square brackets, separating items with commas: `[a, b, c]`. Tuples are constructed by the comma operator (not within square brackets), with or without enclosing parentheses, but an empty tuple must have the enclosing parentheses, such as `a, b, c` or `()`. A single item tuple must have a trailing comma, such as `(d,)`.

Bytearray objects are created with the built-in function `bytearray()`.

Buffer objects are not directly supported by Python syntax, but can be created by calling the built-in function `buffer()`. They don't support concatenation or repetition.

Objects of type `xrange` are similar to buffers in that there is no specific syntax to create them, but they are created using the `xrange()` function. They don't support slicing, concatenation or repetition, and using `in`, `not in`, `min()` or `max()` on them is inefficient.

Most sequence types support the following operations. The `in` and `not in` operations have the same priorities as the comparison operations. The `+` and `*` operations have the same priority as the corresponding numeric operations.<sup>3</sup> Additional methods are provided for *Mutable Sequence Types*.

This table lists the sequence operations sorted in ascending priority (operations in the same box have the same priority). In the table, *s* and *t* are sequences of the same type; *n*, *i* and *j* are integers:

Operation	Result	Notes
<code>x in s</code>	True if an item of <i>s</i> is equal to <i>x</i> , else False	(1)
<code>x not in s</code>	False if an item of <i>s</i> is equal to <i>x</i> , else True	(1)
<code>s + t</code>	the concatenation of <i>s</i> and <i>t</i>	(6)
<code>s * n, n * s</code>	<i>n</i> shallow copies of <i>s</i> concatenated	(2)
<code>s[i]</code>	<i>i</i> th item of <i>s</i> , origin 0	(3)
<code>s[i:j]</code>	slice of <i>s</i> from <i>i</i> to <i>j</i>	(3)(4)
<code>s[i:j:k]</code>	slice of <i>s</i> from <i>i</i> to <i>j</i> with step <i>k</i>	(3)(5)
<code>len(s)</code>	length of <i>s</i>	
<code>min(s)</code>	smallest item of <i>s</i>	
<code>max(s)</code>	largest item of <i>s</i>	
<code>s.index(i)</code>	index of the first occurrence of <i>i</i> in <i>s</i>	
<code>s.count(i)</code>	total number of occurrences of <i>i</i> in <i>s</i>	

Sequence types also support comparisons. In particular, tuples and lists are compared lexicographically by comparing corresponding elements. This means that to compare equal, every element must compare equal and the two sequences must be of the same type and have the same length. (For full details see *comparisons* in the language reference.)

<sup>3</sup> They must have since the parser can't tell the type of the operands.

Notes:

1. When *s* is a string or Unicode string object the `in` and `not in` operations act like a substring test. In Python versions before 2.3, *x* had to be a string of length 1. In Python 2.3 and beyond, *x* may be a string of any length.
2. Values of *n* less than 0 are treated as 0 (which yields an empty sequence of the same type as *s*). Note also that the copies are shallow; nested structures are not copied. This often haunts new Python programmers; consider:

```
>>> lists = [[]] * 3
>>> lists
[[], [], []]
>>> lists[0].append(3)
>>> lists
[[3], [3], [3]]
```

What has happened is that `[[]]` is a one-element list containing an empty list, so all three elements of `[[]] * 3` are (pointers to) this single empty list. Modifying any of the elements of `lists` modifies this single list. You can create a list of different lists this way:

```
>>> lists = [[] for i in range(3)]
>>> lists[0].append(3)
>>> lists[1].append(5)
>>> lists[2].append(7)
>>> lists
[[3], [5], [7]]
```

3. If *i* or *j* is negative, the index is relative to the end of the string: `len(s) + i` or `len(s) + j` is substituted. But note that `-0` is still 0.
4. The slice of *s* from *i* to *j* is defined as the sequence of items with index *k* such that  $i \leq k < j$ . If *i* or *j* is greater than `len(s)`, use `len(s)`. If *i* is omitted or `None`, use 0. If *j* is omitted or `None`, use `len(s)`. If *i* is greater than or equal to *j*, the slice is empty.
5. The slice of *s* from *i* to *j* with step *k* is defined as the sequence of items with index  $x = i + n*k$  such that  $0 \leq n < (j-i)/k$ . In other words, the indices are *i*, *i+k*, *i+2\*k*, *i+3\*k* and so on, stopping when *j* is reached (but never including *j*). If *i* or *j* is greater than `len(s)`, use `len(s)`. If *i* or *j* are omitted or `None`, they become “end” values (which end depends on the sign of *k*). Note, *k* cannot be zero. If *k* is `None`, it is treated like 1.
6. **CPython implementation detail:** If *s* and *t* are both strings, some Python implementations such as CPython can usually perform an in-place optimization for assignments of the form `s = s + t` or `s += t`. When applicable, this optimization makes quadratic run-time much less likely. This optimization is both version and implementation dependent. For performance sensitive code, it is preferable to use the `str.join()` method which assures consistent linear concatenation performance across versions and implementations. Changed in version 2.4: Formerly, string concatenation never occurred in-place.

## 5.6.1 String Methods

Below are listed the string methods which both 8-bit strings and Unicode objects support. Some of them are also available on `bytearray` objects.

In addition, Python’s strings support the sequence type methods described in the *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange* section. To output formatted strings use template strings or the `%` operator described in the *String Formatting Operations* section. Also, see the `re` module for string functions based on regular expressions.

`str.capitalize()`

Return a copy of the string with its first character capitalized and the rest lowercased.

For 8-bit strings, this method is locale-dependent.

- 
- `str.center` (*width* [, *fillchar* ])
- Return centered in a string of length *width*. Padding is done using the specified *fillchar* (default is a space). Changed in version 2.4: Support for the *fillchar* argument.
- `str.count` (*sub* [, *start* [, *end* ] ])
- Return the number of non-overlapping occurrences of substring *sub* in the range [*start*, *end*]. Optional arguments *start* and *end* are interpreted as in slice notation.
- `str.decode` ([*encoding* [, *errors* ] ])
- Decodes the string using the codec registered for *encoding*. *encoding* defaults to the default string encoding. *errors* may be given to set a different error handling scheme. The default is 'strict', meaning that encoding errors raise `UnicodeError`. Other possible values are 'ignore', 'replace' and any other name registered via `codecs.register_error()`, see section *Codec Base Classes*. New in version 2.2. Changed in version 2.3: Support for other error handling schemes added. Changed in version 2.7: Support for keyword arguments added.
- `str.encode` ([*encoding* [, *errors* ] ])
- Return an encoded version of the string. Default encoding is the current default string encoding. *errors* may be given to set a different error handling scheme. The default for *errors* is 'strict', meaning that encoding errors raise a `UnicodeError`. Other possible values are 'ignore', 'replace', 'xmlcharrefreplace', 'backslashreplace' and any other name registered via `codecs.register_error()`, see section *Codec Base Classes*. For a list of possible encodings, see section *Standard Encodings*. New in version 2.0. Changed in version 2.3: Support for 'xmlcharrefreplace' and 'backslashreplace' and other error handling schemes added. Changed in version 2.7: Support for keyword arguments added.
- `str.endswith` (*suffix* [, *start* [, *end* ] ])
- Return True if the string ends with the specified *suffix*, otherwise return False. *suffix* can also be a tuple of suffixes to look for. With optional *start*, test beginning at that position. With optional *end*, stop comparing at that position. Changed in version 2.5: Accept tuples as *suffix*.
- `str.expandtabs` ([*tabsize* ])
- Return a copy of the string where all tab characters are replaced by one or more spaces, depending on the current column and the given tab size. The column number is reset to zero after each newline occurring in the string. If *tabsize* is not given, a tab size of 8 characters is assumed. This doesn't understand other non-printing characters or escape sequences.
- `str.find` (*sub* [, *start* [, *end* ] ])
- Return the lowest index in the string where substring *sub* is found, such that *sub* is contained in the slice `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return -1 if *sub* is not found.

---

**Note:** The `find()` method should be used only if you need to know the position of *sub*. To check if *sub* is a substring or not, use the `in` operator:

```
>>> 'Py' in 'Python'
True
```

- 
- `str.format` (*\*args*, *\*\*kwargs*)
- Perform a string formatting operation. The string on which this method is called can contain literal text or replacement fields delimited by braces `{}`. Each replacement field contains either the numeric index of a positional argument, or the name of a keyword argument. Returns a copy of the string where each replacement field is replaced with the string value of the corresponding argument.

```
>>> "The sum of 1 + 2 is {0}".format(1+2)
'The sum of 1 + 2 is 3'
```

See *Format String Syntax* for a description of the various formatting options that can be specified in format strings.

This method of string formatting is the new standard in Python 3, and should be preferred to the `%` formatting described in *String Formatting Operations* in new code. New in version 2.6.

`str.index(sub[, start[, end]])`

Like `find()`, but raise `ValueError` when the substring is not found.

`str.isalnum()`

Return true if all characters in the string are alphanumeric and there is at least one character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.isalpha()`

Return true if all characters in the string are alphabetic and there is at least one character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.isdigit()`

Return true if all characters in the string are digits and there is at least one character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.islower()`

Return true if all cased characters<sup>4</sup> in the string are lowercase and there is at least one cased character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.isspace()`

Return true if there are only whitespace characters in the string and there is at least one character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.istitle()`

Return true if the string is a titlecased string and there is at least one character, for example uppercase characters may only follow uncased characters and lowercase characters only cased ones. Return false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.isupper()`

Return true if all cased characters<sup>4</sup> in the string are uppercase and there is at least one cased character, false otherwise.

For 8-bit strings, this method is locale-dependent.

`str.join(iterable)`

Return a string which is the concatenation of the strings in the *iterable* *iterable*. The separator between elements is the string providing this method.

`str.ljust(width[, fillchar])`

Return the string left justified in a string of length *width*. Padding is done using the specified *fillchar* (default is a space). The original string is returned if *width* is less than or equal to `len(s)`. Changed in version 2.4: Support for the *fillchar* argument.

`str.lower()`

Return a copy of the string with all the cased characters<sup>4</sup> converted to lowercase.

For 8-bit strings, this method is locale-dependent.

---

<sup>4</sup> Cased characters are those with general category property being one of “Lu” (Letter, uppercase), “Ll” (Letter, lowercase), or “Lt” (Letter, titlecase).

`str.lstrip([chars])`

Return a copy of the string with leading characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a prefix; rather, all combinations of its values are stripped:

```
>>> '  spacious  '.lstrip()
'spacious  '
>>> 'www.example.com'.lstrip('cmowz.')
'example.com'
```

Changed in version 2.2.2: Support for the *chars* argument.

`str.partition(sep)`

Split the string at the first occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing the string itself, followed by two empty strings. New in version 2.5.

`str.replace(old, new[, count])`

Return a copy of the string with all occurrences of substring *old* replaced by *new*. If the optional argument *count* is given, only the first *count* occurrences are replaced.

`str.rfind(sub[, start[, end]])`

Return the highest index in the string where substring *sub* is found, such that *sub* is contained within `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return `-1` on failure.

`str.rindex(sub[, start[, end]])`

Like `rfind()` but raises `ValueError` when the substring *sub* is not found.

`str.rjust(width[, fillchar])`

Return the string right justified in a string of length *width*. Padding is done using the specified *fillchar* (default is a space). The original string is returned if *width* is less than or equal to `len(s)`. Changed in version 2.4: Support for the *fillchar* argument.

`str.rpartition(sep)`

Split the string at the last occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing two empty strings, followed by the string itself. New in version 2.5.

`str.rsplit([sep[, maxsplit]])`

Return a list of the words in the string, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done, the *rightmost* ones. If *sep* is not specified or `None`, any whitespace string is a separator. Except for splitting from the right, `rsplit()` behaves like `split()` which is described in detail below. New in version 2.4.

`str.rstrip([chars])`

Return a copy of the string with trailing characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a suffix; rather, all combinations of its values are stripped:

```
>>> '  spacious  '.rstrip()
'spacious'
>>> 'mississippi'.rstrip('ipz')
'mississ'
```

Changed in version 2.2.2: Support for the *chars* argument.

`str.split([sep[, maxsplit]])`

Return a list of the words in the string, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done (thus, the list will have at most *maxsplit*+1 elements). If *maxsplit* is not specified or -1, then there is no limit on the number of splits (all possible splits are made).

If *sep* is given, consecutive delimiters are not grouped together and are deemed to delimit empty strings (for example, `'1,,2'.split(',')` returns `['1', '', '2']`). The *sep* argument may consist of multiple characters (for example, `'1<>2<>3'.split('<>')` returns `['1', '2', '3']`). Splitting an empty string with a specified separator returns `["]`.

If *sep* is not specified or is `None`, a different splitting algorithm is applied: runs of consecutive whitespace are regarded as a single separator, and the result will contain no empty strings at the start or end if the string has leading or trailing whitespace. Consequently, splitting an empty string or a string consisting of just whitespace with a `None` separator returns `[]`.

For example, `' 1 2 3 '.split()` returns `['1', '2', '3']`, and `' 1 2 3 '.split(None, 1)` returns `['1', '2 3 ']`.

`str.splitlines([keepends])`

Return a list of the lines in the string, breaking at line boundaries. This method uses the *universal newlines* approach to splitting lines. Line breaks are not included in the resulting list unless *keepends* is given and true.

For example, `'ab c\n\nde fg\rkl\r\n'.splitlines()` returns `['ab c', '', 'de fg', 'kl']`, while the same call with `splitlines(True)` returns `['ab c\n', '\n', 'de fg\r', 'kl\r\n']`.

Unlike `split()` when a delimiter string *sep* is given, this method returns an empty list for the empty string, and a terminal line break does not result in an extra line.

`str.startswith(prefix[, start[, end]])`

Return `True` if string starts with the *prefix*, otherwise return `False`. *prefix* can also be a tuple of prefixes to look for. With optional *start*, test string beginning at that position. With optional *end*, stop comparing string at that position. Changed in version 2.5: Accept tuples as *prefix*.

`str.strip([chars])`

Return a copy of the string with the leading and trailing characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```
>>> '  spacious  '.strip()
'spacious'
>>> 'www.example.com'.strip('cmowz.')
'example'
```

Changed in version 2.2.2: Support for the *chars* argument.

`str.swapcase()`

Return a copy of the string with uppercase characters converted to lowercase and vice versa.

For 8-bit strings, this method is locale-dependent.

`str.title()`

Return a titlecased version of the string where words start with an uppercase character and the remaining characters are lowercase.

The algorithm uses a simple language-independent definition of a word as groups of consecutive letters. The definition works in many contexts but it means that apostrophes in contractions and possessives form word boundaries, which may not be the desired result:

```
>>> "they're bill's friends from the UK".title()
'They'Re Bill'S Friends From The Uk'
```

A workaround for apostrophes can be constructed using regular expressions:

```
>>> import re
>>> def titlecase(s):
    return re.sub(r"[A-Za-z]+(' [A-Za-z]+)?",
                  lambda mo: mo.group(0)[0].upper() +
                             mo.group(0)[1:].lower(),
                  s)

>>> titlecase("they're bill's friends.")
'They're Bill's Friends.'
```

For 8-bit strings, this method is locale-dependent.

`str.translate(table[, deletechars])`

Return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table, which must be a string of length 256.

You can use the `maketrans()` helper function in the `string` module to create a translation table. For string objects, set the *table* argument to `None` for translations that only delete characters:

```
>>> 'read this short text'.translate(None, 'aeiou')
'rd ths shrt txt'
```

New in version 2.6: Support for a `None` *table* argument. For Unicode objects, the `translate()` method does not accept the optional *deletechars* argument. Instead, it returns a copy of the *s* where all characters have been mapped through the given translation table which must be a mapping of Unicode ordinals to Unicode ordinals, Unicode strings or `None`. Unmapped characters are left untouched. Characters mapped to `None` are deleted. Note, a more flexible approach is to create a custom character mapping codec using the `codecs` module (see `encodings.cp1251` for an example).

`str.upper()`

Return a copy of the string with all the cased characters <sup>4</sup> converted to uppercase. Note that `str.upper().isupper()` might be `False` if *s* contains uncased characters or if the Unicode category of the resulting character(s) is not “Lu” (Letter, uppercase), but e.g. “Lt” (Letter, titlecase).

For 8-bit strings, this method is locale-dependent.

`str.zfill(width)`

Return the numeric string left filled with zeros in a string of length *width*. A sign prefix is handled correctly. The original string is returned if *width* is less than or equal to `len(s)`. New in version 2.2.2.

The following methods are present only on unicode objects:

`unicode.isnumeric()`

Return `True` if there are only numeric characters in *S*, `False` otherwise. Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. U+2155, VULGAR FRACTION ONE FIFTH.

`unicode.isdecimal()`

Return `True` if there are only decimal characters in *S*, `False` otherwise. Decimal characters include digit characters, and all characters that can be used to form decimal-radix numbers, e.g. U+0660, ARABIC-INDIC DIGIT ZERO.

## 5.6.2 String Formatting Operations

String and Unicode objects have one unique built-in operation: the `%` operator (modulo). This is also known as the string *formatting* or *interpolation* operator. Given `format % values` (where *format* is a string or Unicode object), `%` conversion specifications in *format* are replaced with zero or more elements of *values*. The effect is similar to the using `sprintf()` in the C language. If *format* is a Unicode object, or if any of the objects being converted using the `%s` conversion are Unicode objects, the result will also be a Unicode object.

If *format* requires a single argument, *values* may be a single non-tuple object.<sup>5</sup> Otherwise, *values* must be a tuple with exactly the number of items specified by the format string, or a single mapping object (for example, a dictionary).

A conversion specifier contains two or more characters and has the following components, which must occur in this order:

1. The `'%'` character, which marks the start of the specifier.
2. Mapping key (optional), consisting of a parenthesised sequence of characters (for example, `(somename)`).
3. Conversion flags (optional), which affect the result of some conversion types.
4. Minimum field width (optional). If specified as an `'*'` (asterisk), the actual width is read from the next element of the tuple in *values*, and the object to convert comes after the minimum field width and optional precision.
5. Precision (optional), given as a `'.'` (dot) followed by the precision. If specified as `'*'` (an asterisk), the actual width is read from the next element of the tuple in *values*, and the value to convert comes after the precision.
6. Length modifier (optional).
7. Conversion type.

When the right argument is a dictionary (or other mapping type), then the formats in the string *must* include a parenthesised mapping key into that dictionary inserted immediately after the `'%'` character. The mapping key selects the value to be formatted from the mapping. For example:

```
>>> print '%(language)s has %(number)03d quote types.' % \
...     {"language": "Python", "number": 2}
Python has 002 quote types.
```

In this case no `*` specifiers may occur in a format (since they require a sequential parameter list).

The conversion flag characters are:

Flag	Meaning
<code>'#'</code>	The value conversion will use the “alternate form” (where defined below).
<code>'0'</code>	The conversion will be zero padded for numeric values.
<code>'-'</code>	The converted value is left adjusted (overrides the <code>'0'</code> conversion if both are given).
<code>' '</code>	(a space) A blank should be left before a positive number (or empty string) produced by a signed conversion.
<code>'+'</code>	A sign character ( <code>'+'</code> or <code>'-'</code> ) will precede the conversion (overrides a “space” flag).

A length modifier (h, l, or L) may be present, but is ignored as it is not necessary for Python – so e.g. `%ld` is identical to `%d`.

The conversion types are:

<sup>5</sup> To format only a tuple you should therefore provide a singleton tuple whose only element is the tuple to be formatted.

Conversion	Meaning	Notes
'd'	Signed integer decimal.	
'i'	Signed integer decimal.	
'o'	Signed octal value.	(1)
'u'	Obsolete type – it is identical to 'd'.	(7)
'x'	Signed hexadecimal (lowercase).	(2)
'X'	Signed hexadecimal (uppercase).	(2)
'e'	Floating point exponential format (lowercase).	(3)
'E'	Floating point exponential format (uppercase).	(3)
'f'	Floating point decimal format.	(3)
'F'	Floating point decimal format.	(3)
'g'	Floating point format. Uses lowercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'G'	Floating point format. Uses uppercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'c'	Single character (accepts integer or single character string).	
'r'	String (converts any Python object using <code>repr()</code> ).	(5)
's'	String (converts any Python object using <code>str()</code> ).	(6)
'%'	No argument is converted, results in a '%' character in the result.	

Notes:

- The alternate form causes a leading zero ('0') to be inserted between left-hand padding and the formatting of the number if the leading character of the result is not already a zero.
- The alternate form causes a leading '0x' or '0X' (depending on whether the 'x' or 'X' format was used) to be inserted between left-hand padding and the formatting of the number if the leading character of the result is not already a zero.
- The alternate form causes the result to always contain a decimal point, even if no digits follow it.  
The precision determines the number of digits after the decimal point and defaults to 6.
- The alternate form causes the result to always contain a decimal point, and trailing zeroes are not removed as they would otherwise be.  
The precision determines the number of significant digits before and after the decimal point and defaults to 6.
- The %r conversion was added in Python 2.0.  
The precision determines the maximal number of characters used.
- If the object or format provided is a `unicode` string, the resulting string will also be `unicode`.  
The precision determines the maximal number of characters used.
- See [PEP 237](#).

Since Python strings have an explicit length, %s conversions do not assume that '\0' is the end of the string. Changed in version 2.7: %f conversions for numbers whose absolute value is over 1e50 are no longer replaced by %g conversions. Additional string operations are defined in standard modules `string` and `re`.

### 5.6.3 xrange Type

The `xrange` type is an immutable sequence which is commonly used for looping. The advantage of the `xrange` type is that an `xrange` object will always take the same amount of memory, no matter the size of the range it represents. There are no consistent performance advantages.

XRange objects have very little behavior: they only support indexing, iteration, and the `len()` function.

## 5.6.4 Mutable Sequence Types

List and `bytearray` objects support additional operations that allow in-place modification of the object. Other mutable sequence types (when added to the language) should also support these operations. Strings and tuples are immutable sequence types: such objects cannot be modified once created. The following operations are defined on mutable sequence types (where  $x$  is an arbitrary object):

Operation	Result	Notes
<code>s[i] = x</code> <code>s[i:j] = t</code>	item $i$ of $s$ is replaced by $x$ slice of $s$ from $i$ to $j$ is replaced by the contents of the iterable $t$	
<code>del s[i:j]</code> <code>s[i:j:k] = t</code> <code>del s[i:j:k]</code>	same as <code>s[i:j] = []</code> the elements of <code>s[i:j:k]</code> are replaced by those of $t$ removes the elements of <code>s[i:j:k]</code> from the list	(1)
<code>s.append(x)</code>	same as <code>s[len(s):len(s)] = [x]</code>	(2)
<code>s.extend(x)</code>	same as <code>s[len(s):len(s)] = x</code>	(3)
<code>s.count(x)</code>	return number of $i$ 's for which <code>s[i] == x</code>	
<code>s.index(x[, i[, j]])</code>	return smallest $k$ such that <code>s[k] == x</code> and $i \leq k < j$	(4)
<code>s.insert(i, x)</code>	same as <code>s[i:i] = [x]</code>	(5)
<code>s.pop([i])</code>	same as <code>x = s[i]; del s[i]; return x</code>	(6)
<code>s.remove(x)</code>	same as <code>del s[s.index(x)]</code>	(4)
<code>s.reverse()</code>	reverses the items of $s$ in place	(7)
<code>s.sort([cmp[, key[, reverse]])</code>	sort the items of $s$ in place	(7)(8)(9)(10)

Notes:

- $t$  must have the same length as the slice it is replacing.
- The C implementation of Python has historically accepted multiple parameters and implicitly joined them into a tuple; this no longer works in Python 2.0. Use of this misfeature has been deprecated since Python 1.4.
- $x$  can be any iterable object.
- Raises `ValueError` when  $x$  is not found in  $s$ . When a negative index is passed as the second or third parameter to the `index()` method, the list length is added, as for slice indices. If it is still negative, it is truncated to zero, as for slice indices. Changed in version 2.3: Previously, `index()` didn't have arguments for specifying start and stop positions.
- When a negative index is passed as the first parameter to the `insert()` method, the list length is added, as for slice indices. If it is still negative, it is truncated to zero, as for slice indices. Changed in version 2.3: Previously, all negative indices were truncated to zero.
- The `pop()` method is only supported by the list and array types. The optional argument  $i$  defaults to  $-1$ , so that by default the last item is removed and returned.
- The `sort()` and `reverse()` methods modify the list in place for economy of space when sorting or reversing a large list. To remind you that they operate by side effect, they don't return the sorted or reversed list.
- The `sort()` method takes optional arguments for controlling the comparisons.

`cmp` specifies a custom comparison function of two arguments (list items) which should return a negative, zero or positive number depending on whether the first argument is considered smaller than, equal to, or larger than the second argument: `cmp=lambda x,y: cmp(x.lower(), y.lower())`. The default value is `None`.

`key` specifies a function of one argument that is used to extract a comparison key from each list element: `key=str.lower`. The default value is `None`.

`reverse` is a boolean value. If set to `True`, then the list elements are sorted as if each comparison were reversed.

In general, the *key* and *reverse* conversion processes are much faster than specifying an equivalent *cmp* function. This is because *cmp* is called multiple times for each list element while *key* and *reverse* touch each element only once. Use `functools.cmp_to_key()` to convert an old-style *cmp* function to a *key* function. Changed in version 2.3: Support for `None` as an equivalent to omitting *cmp* was added. Changed in version 2.4: Support for *key* and *reverse* was added.

9. Starting with Python 2.3, the `sort()` method is guaranteed to be stable. A sort is stable if it guarantees not to change the relative order of elements that compare equal — this is helpful for sorting in multiple passes (for example, sort by department, then by salary grade).
10. **CPython implementation detail:** While a list is being sorted, the effect of attempting to mutate, or even inspect, the list is undefined. The C implementation of Python 2.3 and newer makes the list appear empty for the duration, and raises `ValueError` if it can detect that the list has been mutated during a sort.

## 5.7 Set Types — set, frozenset

A *set* object is an unordered collection of distinct *hashable* objects. Common uses include membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference. (For other containers see the built in `dict`, `list`, and `tuple` classes, and the `collections` module.) New in version 2.4. Like other collections, sets support `x in set`, `len(set)`, and `for x in set`. Being an unordered collection, sets do not record element position or order of insertion. Accordingly, sets do not support indexing, slicing, or other sequence-like behavior.

There are currently two built-in set types, `set` and `frozenset`. The `set` type is mutable — the contents can be changed using methods like `add()` and `remove()`. Since it is mutable, it has no hash value and cannot be used as either a dictionary key or as an element of another set. The `frozenset` type is immutable and *hashable* — its contents cannot be altered after it is created; it can therefore be used as a dictionary key or as an element of another set.

As of Python 2.7, non-empty sets (not frozensets) can be created by placing a comma-separated list of elements within braces, for example: `{'jack', 'sjoerd'}`, in addition to the `set` constructor.

The constructors for both classes work the same:

```
class set ([iterable])
```

```
class frozenset ([iterable])
```

Return a new set or frozenset object whose elements are taken from *iterable*. The elements of a set must be hashable. To represent sets of sets, the inner sets must be `frozenset` objects. If *iterable* is not specified, a new empty set is returned.

Instances of `set` and `frozenset` provide the following operations:

```
len(s)
```

Return the cardinality of set *s*.

```
x in s
```

Test *x* for membership in *s*.

```
x not in s
```

Test *x* for non-membership in *s*.

```
isdisjoint (other)
```

Return True if the set has no elements in common with *other*. Sets are disjoint if and only if their intersection is the empty set. New in version 2.6.

```
issubset (other)
```

```
set <= other
```

Test whether every element in the set is in *other*.

**set** < **other**

Test whether the set is a true subset of *other*, that is, `set <= other` and `set != other`.

**issuperset** (*other*)**set** >= **other**

Test whether every element in *other* is in the set.

**set** > **other**

Test whether the set is a true superset of *other*, that is, `set >= other` and `set != other`.

**union** (*other*, ...)**set** | **other** | ...

Return a new set with elements from the set and all others. Changed in version 2.6: Accepts multiple input iterables.

**intersection** (*other*, ...)**set** & **other** & ...

Return a new set with elements common to the set and all others. Changed in version 2.6: Accepts multiple input iterables.

**difference** (*other*, ...)**set** - **other** - ...

Return a new set with elements in the set that are not in the others. Changed in version 2.6: Accepts multiple input iterables.

**symmetric\_difference** (*other*)**set** ^ **other**

Return a new set with elements in either the set or *other* but not both.

**copy** ()

Return a new set with a shallow copy of *s*.

Note, the non-operator versions of `union()`, `intersection()`, `difference()`, and `symmetric_difference()`, `issubset()`, and `issuperset()` methods will accept any iterable as an argument. In contrast, their operator based counterparts require their arguments to be sets. This precludes error-prone constructions like `set('abc') & 'cbs'` in favor of the more readable `set('abc').intersection('cbs')`.

Both `set` and `frozenset` support set to set comparisons. Two sets are equal if and only if every element of each set is contained in the other (each is a subset of the other). A set is less than another set if and only if the first set is a proper subset of the second set (is a subset, but is not equal). A set is greater than another set if and only if the first set is a proper superset of the second set (is a superset, but is not equal).

Instances of `set` are compared to instances of `frozenset` based on their members. For example, `set('abc') == frozenset('abc')` returns `True` and so does `set('abc')` in `set([frozenset('abc')])`.

The subset and equality comparisons do not generalize to a complete ordering function. For example, any two disjoint sets are not equal and are not subsets of each other, so *all* of the following return `False`: `a<b`, `a==b`, or `a>b`. Accordingly, sets do not implement the `__cmp__()` method.

Since sets only define partial ordering (subset relationships), the output of the `list.sort()` method is undefined for lists of sets.

Set elements, like dictionary keys, must be *hashable*.

Binary operations that mix `set` instances with `frozenset` return the type of the first operand. For example: `frozenset('ab') | set('bc')` returns an instance of `frozenset`.

The following table lists operations available for `set` that do not apply to immutable instances of `frozenset`:

**update** (*other*, ...)

**set** `|= other | ...`

Update the set, adding elements from all others. Changed in version 2.6: Accepts multiple input iterables.

**intersection\_update** (*other, ...*)

**set** `&= other & ...`

Update the set, keeping only elements found in it and all others. Changed in version 2.6: Accepts multiple input iterables.

**difference\_update** (*other, ...*)

**set** `--= other | ...`

Update the set, removing elements found in others. Changed in version 2.6: Accepts multiple input iterables.

**symmetric\_difference\_update** (*other*)

**set** `^= other`

Update the set, keeping only elements found in either set, but not in both.

**add** (*elem*)

Add element *elem* to the set.

**remove** (*elem*)

Remove element *elem* from the set. Raises `KeyError` if *elem* is not contained in the set.

**discard** (*elem*)

Remove element *elem* from the set if it is present.

**pop** ()

Remove and return an arbitrary element from the set. Raises `KeyError` if the set is empty.

**clear** ()

Remove all elements from the set.

Note, the non-operator versions of the `update()`, `intersection_update()`, `difference_update()`, and `symmetric_difference_update()` methods will accept any iterable as an argument.

Note, the *elem* argument to the `__contains__()`, `remove()`, and `discard()` methods may be a set. To support searching for an equivalent frozenset, the *elem* set is temporarily mutated during the search and then restored. During the search, the *elem* set should not be read or mutated since it does not have a meaningful value.

#### See Also:

*Comparison to the built-in set types* Differences between the `sets` module and the built-in set types.

## 5.8 Mapping Types — dict

A *mapping* object maps *hashable* values to arbitrary objects. Mappings are mutable objects. There is currently only one standard mapping type, the *dictionary*. (For other containers see the built in `list`, `set`, and `tuple` classes, and the `collections` module.)

A dictionary's keys are *almost* arbitrary values. Values that are not *hashable*, that is, values containing lists, dictionaries or other mutable types (that are compared by value rather than by object identity) may not be used as keys. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (such as 1 and 1.0) then they can be used interchangeably to index the same dictionary entry. (Note however, that since computers store floating-point numbers as approximations it is usually unwise to use them as dictionary keys.)

Dictionaries can be created by placing a comma-separated list of `key: value` pairs within braces, for example: `{'jack': 4098, 'sjoerd': 4127}` or `{4098: 'jack', 4127: 'sjoerd'}`, or by the `dict` constructor.

**class** `dict` (*[arg]*)

Return a new dictionary initialized from an optional positional argument or from a set of keyword arguments. If no arguments are given, return a new empty dictionary. If the positional argument *arg* is a mapping object, return a dictionary mapping the same keys to the same values as does the mapping object. Otherwise the positional argument must be a sequence, a container that supports iteration, or an iterator object. The elements of the argument must each also be of one of those kinds, and each must in turn contain exactly two objects. The first is used as a key in the new dictionary, and the second as the key's value. If a given key is seen more than once, the last value associated with it is retained in the new dictionary.

If keyword arguments are given, the keywords themselves with their associated values are added as items to the dictionary. If a key is specified both in the positional argument and as a keyword argument, the value associated with the keyword is retained in the dictionary. For example, these all return a dictionary equal to `{"one": 1, "two": 2}`:

```
•dict(one=1, two=2)
•dict({'one': 1, 'two': 2})
•dict(zip(('one', 'two'), (1, 2)))
•dict(['two', 2], ['one', 1])
```

The first example only works for keys that are valid Python identifiers; the others work with any valid keys. New in version 2.2.Changed in version 2.3: Support for building a dictionary from keyword arguments added. These are the operations that dictionaries support (and therefore, custom mapping types should support too):

**len** (*d*)

Return the number of items in the dictionary *d*.

**d[key]**

Return the item of *d* with key *key*. Raises a `KeyError` if *key* is not in the map. New in version 2.5: If a subclass of `dict` defines a method `__missing__()`, if the key *key* is not present, the `d[key]` operation calls that method with the key *key* as argument. The `d[key]` operation then returns or raises whatever is returned or raised by the `__missing__(key)` call if the key is not present. No other operations or methods invoke `__missing__()`. If `__missing__()` is not defined, `KeyError` is raised. `__missing__()` must be a method; it cannot be an instance variable. For an example, see `collections.defaultdict`.

**d[key] = value**

Set `d[key]` to *value*.

**del d[key]**

Remove `d[key]` from *d*. Raises a `KeyError` if *key* is not in the map.

**key in d**

Return `True` if *d* has a key *key*, else `False`. New in version 2.2.

**key not in d**

Equivalent to `not key in d`. New in version 2.2.

**iter** (*d*)

Return an iterator over the keys of the dictionary. This is a shortcut for `iterkeys()`.

**clear** ()

Remove all items from the dictionary.

**copy** ()

Return a shallow copy of the dictionary.

**fromkeys** (*seq* [, *value* ])

Create a new dictionary with keys from *seq* and values set to *value*.

`fromkeys()` is a class method that returns a new dictionary. *value* defaults to `None`. New in version 2.3.

**get** (*key* [, *default* ])

Return the value for *key* if *key* is in the dictionary, else *default*. If *default* is not given, it defaults to `None`, so that this method never raises a `KeyError`.

**has\_key** (*key*)

Test for the presence of *key* in the dictionary. `has_key()` is deprecated in favor of `key in d`.

**items** ()

Return a copy of the dictionary's list of (*key*, *value*) pairs.

**CPython implementation detail:** Keys and values are listed in an arbitrary order which is non-random, varies across Python implementations, and depends on the dictionary's history of insertions and deletions.

If `items()`, `keys()`, `values()`, `iteritems()`, `iterkeys()`, and `itervalues()` are called with no intervening modifications to the dictionary, the lists will directly correspond. This allows the creation of (*value*, *key*) pairs using `zip()`: `pairs = zip(d.values(), d.keys())`. The same relationship holds for the `iterkeys()` and `itervalues()` methods: `pairs = zip(d.itervalues(), d.iterkeys())` provides the same value for pairs. Another way to create the same list is `pairs = [(v, k) for (k, v) in d.iteritems()]`.

**iteritems** ()

Return an iterator over the dictionary's (*key*, *value*) pairs. See the note for `dict.items()`.

Using `iteritems()` while adding or deleting entries in the dictionary may raise a `RuntimeError` or fail to iterate over all entries. New in version 2.2.

**iterkeys** ()

Return an iterator over the dictionary's keys. See the note for `dict.items()`.

Using `iterkeys()` while adding or deleting entries in the dictionary may raise a `RuntimeError` or fail to iterate over all entries. New in version 2.2.

**itervalues** ()

Return an iterator over the dictionary's values. See the note for `dict.items()`.

Using `itervalues()` while adding or deleting entries in the dictionary may raise a `RuntimeError` or fail to iterate over all entries. New in version 2.2.

**keys** ()

Return a copy of the dictionary's list of keys. See the note for `dict.items()`.

**pop** (*key* [, *default* ])

If *key* is in the dictionary, remove it and return its value, else return *default*. If *default* is not given and *key* is not in the dictionary, a `KeyError` is raised. New in version 2.3.

**popitem** ()

Remove and return an arbitrary (*key*, *value*) pair from the dictionary.

`popitem()` is useful to destructively iterate over a dictionary, as often used in set algorithms. If the dictionary is empty, calling `popitem()` raises a `KeyError`.

**setdefault** (*key* [, *default* ])

If *key* is in the dictionary, return its value. If not, insert *key* with a value of *default* and return *default*. *default* defaults to `None`.

**update** ([*other* ])

Update the dictionary with the key/value pairs from *other*, overwriting existing keys. Return `None`.

`update()` accepts either another dictionary object or an iterable of key/value pairs (as tuples or other iterables of length two). If keyword arguments are specified, the dictionary is then updated with those key/value pairs: `d.update(red=1, blue=2)`. Changed in version 2.4: Allowed the argument to be an iterable of key/value pairs and allowed keyword arguments.

### **values()**

Return a copy of the dictionary's list of values. See the note for `dict.items()`.

### **viewitems()**

Return a new view of the dictionary's items ((`key`, `value`) pairs). See below for documentation of view objects. New in version 2.7.

### **viewkeys()**

Return a new view of the dictionary's keys. See below for documentation of view objects. New in version 2.7.

### **viewvalues()**

Return a new view of the dictionary's values. See below for documentation of view objects. New in version 2.7.

## 5.8.1 Dictionary view objects

The objects returned by `dict.viewkeys()`, `dict.viewvalues()` and `dict.viewitems()` are *view objects*. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes.

Dictionary views can be iterated over to yield their respective data, and support membership tests:

### **len(dictview)**

Return the number of entries in the dictionary.

### **iter(dictview)**

Return an iterator over the keys, values or items (represented as tuples of (`key`, `value`)) in the dictionary.

Keys and values are iterated over in an arbitrary order which is non-random, varies across Python implementations, and depends on the dictionary's history of insertions and deletions. If keys, values and items views are iterated over with no intervening modifications to the dictionary, the order of items will directly correspond. This allows the creation of (`value`, `key`) pairs using `zip(): pairs = zip(d.values(), d.keys())`. Another way to create the same list is `pairs = [(v, k) for (k, v) in d.items()]`.

Iterating views while adding or deleting entries in the dictionary may raise a `RuntimeError` or fail to iterate over all entries.

### **x in dictview**

Return `True` if `x` is in the underlying dictionary's keys, values or items (in the latter case, `x` should be a (`key`, `value`) tuple).

Keys views are set-like since their entries are unique and hashable. If all values are hashable, so that (`key`, `value`) pairs are unique and hashable, then the items view is also set-like. (Values views are not treated as set-like since the entries are generally not unique.) Then these set operations are available ("other" refers either to another view or a set):

### **dictview & other**

Return the intersection of the dictview and the other object as a new set.

### **dictview | other**

Return the union of the dictview and the other object as a new set.

### **dictview - other**

Return the difference between the dictview and the other object (all elements in *dictview* that aren't in *other*) as a new set.

**dictview ^ other**

Return the symmetric difference (all elements either in *dictview* or *other*, but not in both) of the dictview and the other object as a new set.

An example of dictionary view usage:

```
>>> dishes = {'eggs': 2, 'sausage': 1, 'bacon': 1, 'spam': 500}
>>> keys = dishes.viewkeys()
>>> values = dishes.viewvalues()

>>> # iteration
>>> n = 0
>>> for val in values:
...     n += val
>>> print(n)
504

>>> # keys and values are iterated over in the same order
>>> list(keys)
['eggs', 'bacon', 'sausage', 'spam']
>>> list(values)
[2, 1, 1, 500]

>>> # view objects are dynamic and reflect dict changes
>>> del dishes['eggs']
>>> del dishes['sausage']
>>> list(keys)
['spam', 'bacon']

>>> # set operations
>>> keys & {'eggs', 'bacon', 'salad'}
{'bacon'}
```

## 5.9 File Objects

File objects are implemented using C's `stdio` package and can be created with the built-in `open()` function. File objects are also returned by some other built-in functions and methods, such as `os.popen()` and `os.fdopen()` and the `makefile()` method of socket objects. Temporary files can be created using the `tempfile` module, and high-level file operations such as copying, moving, and deleting files and directories can be achieved with the `shutil` module.

When a file operation fails for an I/O-related reason, the exception `IOError` is raised. This includes situations where the operation is not defined for some reason, like `seek()` on a tty device or writing a file opened for reading.

Files have the following methods:

`file.close()`

Close the file. A closed file cannot be read or written any more. Any operation which requires that the file be open will raise a `ValueError` after the file has been closed. Calling `close()` more than once is allowed.

As of Python 2.5, you can avoid having to call this method explicitly if you use the `with` statement. For example, the following code will automatically close `f` when the `with` block is exited:

```
from __future__ import with_statement # This isn't required in Python 2.6
```

```
with open("hello.txt") as f:
    for line in f:
        print line
```

In older versions of Python, you would have needed to do this to get the same effect:

```
f = open("hello.txt")
try:
    for line in f:
        print line
finally:
    f.close()
```

---

**Note:** Not all “file-like” types in Python support use as a context manager for the `with` statement. If your code is intended to work with any file-like object, you can use the function `contextlib.closing()` instead of using the object directly.

---

`file.flush()`

Flush the internal buffer, like `stdio's fflush()`. This may be a no-op on some file-like objects.

---

**Note:** `flush()` does not necessarily write the file's data to disk. Use `flush()` followed by `os.fsync()` to ensure this behavior.

---

`file.fileno()`

Return the integer “file descriptor” that is used by the underlying implementation to request I/O operations from the operating system. This can be useful for other, lower level interfaces that use file descriptors, such as the `fcntl` module or `os.read()` and friends.

---

**Note:** File-like objects which do not have a real file descriptor should *not* provide this method!

---

`file.isatty()`

Return `True` if the file is connected to a tty(-like) device, else `False`.

---

**Note:** If a file-like object is not associated with a real file, this method should *not* be implemented.

---

`file.next()`

A file object is its own iterator, for example `iter(f)` returns `f` (unless `f` is closed). When a file is used as an iterator, typically in a `for` loop (for example, `for line in f: print line`), the `next()` method is called repeatedly. This method returns the next input line, or raises `StopIteration` when EOF is hit when the file is open for reading (behavior is undefined when the file is open for writing). In order to make a `for` loop the most efficient way of looping over the lines of a file (a very common operation), the `next()` method uses a hidden read-ahead buffer. As a consequence of using a read-ahead buffer, combining `next()` with other file methods (like `readline()`) does not work right. However, using `seek()` to reposition the file to an absolute position will flush the read-ahead buffer. New in version 2.3.

`file.read([size])`

Read at most `size` bytes from the file (less if the read hits EOF before obtaining `size` bytes). If the `size` argument is negative or omitted, read all data until EOF is reached. The bytes are returned as a string object. An empty string is returned when EOF is encountered immediately. (For certain files, like ttys, it makes sense to continue reading after an EOF is hit.) Note that this method may call the underlying C function `fread()` more than

once in an effort to acquire as close to *size* bytes as possible. Also note that when in non-blocking mode, less data than was requested may be returned, even if no *size* parameter was given.

---

**Note:** This function is simply a wrapper for the underlying `fread()` C function, and will behave the same in corner cases, such as whether the EOF value is cached.

---

`file.readline([size])`

Read one entire line from the file. A trailing newline character is kept in the string (but may be absent when a file ends with an incomplete line).<sup>6</sup> If the *size* argument is present and non-negative, it is a maximum byte count (including the trailing newline) and an incomplete line may be returned. When *size* is not 0, an empty string is returned *only* when EOF is encountered immediately.

---

**Note:** Unlike `stdio's fgets()`, the returned string contains null characters (`'\0'`) if they occurred in the input.

---

`file.readlines([sizehint])`

Read until EOF using `readline()` and return a list containing the lines thus read. If the optional *sizehint* argument is present, instead of reading up to EOF, whole lines totalling approximately *sizehint* bytes (possibly after rounding up to an internal buffer size) are read. Objects implementing a file-like interface may choose to ignore *sizehint* if it cannot be implemented, or cannot be implemented efficiently.

`file.xreadlines()`

This method returns the same thing as `iter(f)`. New in version 2.1. Deprecated since version 2.3: Use `for line in file` instead.

`file.seek(offset[, whence])`

Set the file's current position, like `stdio's fseek()`. The *whence* argument is optional and defaults to `os.SEEK_SET` or 0 (absolute file positioning); other values are `os.SEEK_CUR` or 1 (seek relative to the current position) and `os.SEEK_END` or 2 (seek relative to the file's end). There is no return value.

For example, `f.seek(2, os.SEEK_CUR)` advances the position by two and `f.seek(-3, os.SEEK_END)` sets the position to the third to last.

Note that if the file is opened for appending (mode `'a'` or `'a+'`), any `seek()` operations will be undone at the next write. If the file is only opened for writing in append mode (mode `'a'`), this method is essentially a no-op, but it remains useful for files opened in append mode with reading enabled (mode `'a+'`). If the file is opened in text mode (without `'b'`), only offsets returned by `tell()` are legal. Use of other offsets causes undefined behavior.

Note that not all file objects are seekable. Changed in version 2.6: Passing float values as offset has been deprecated.

`file.tell()`

Return the file's current position, like `stdio's ftell()`.

---

**Note:** On Windows, `tell()` can return illegal values (after an `fgets()`) when reading files with Unix-style line-endings. Use binary mode (`'rb'`) to circumvent this problem.

---

`file.truncate([size])`

Truncate the file's size. If the optional *size* argument is present, the file is truncated to (at most) that size. The size defaults to the current position. The current file position is not changed. Note that if a specified size exceeds the file's current size, the result is platform-dependent: possibilities include that the file may remain

---

<sup>6</sup> The advantage of leaving the newline on is that returning an empty string is then an unambiguous EOF indication. It is also possible (in cases where it might matter, for example, if you want to make an exact copy of a file while scanning its lines) to tell whether the last line of a file ended in a newline or not (yes this happens!).

unchanged, increase to the specified size as if zero-filled, or increase to the specified size with undefined new content. Availability: Windows, many Unix variants.

`file.write(str)`

Write a string to the file. There is no return value. Due to buffering, the string may not actually show up in the file until the `flush()` or `close()` method is called.

`file.writelines(sequence)`

Write a sequence of strings to the file. The sequence can be any iterable object producing strings, typically a list of strings. There is no return value. (The name is intended to match `readlines()`; `writelines()` does not add line separators.)

Files support the iterator protocol. Each iteration returns the same result as `readline()`, and iteration ends when the `readline()` method returns an empty string.

File objects also offer a number of other interesting attributes. These are not required for file-like objects, but should be implemented if they make sense for the particular object.

`file.closed`

bool indicating the current state of the file object. This is a read-only attribute; the `close()` method changes the value. It may not be available on all file-like objects.

`file.encoding`

The encoding that this file uses. When Unicode strings are written to a file, they will be converted to byte strings using this encoding. In addition, when the file is connected to a terminal, the attribute gives the encoding that the terminal is likely to use (that information might be incorrect if the user has misconfigured the terminal). The attribute is read-only and may not be present on all file-like objects. It may also be `None`, in which case the file uses the system default encoding for converting Unicode strings. New in version 2.3.

`file.errors`

The Unicode error handler used along with the encoding. New in version 2.6.

`file.mode`

The I/O mode for the file. If the file was created using the `open()` built-in function, this will be the value of the `mode` parameter. This is a read-only attribute and may not be present on all file-like objects.

`file.name`

If the file object was created using `open()`, the name of the file. Otherwise, some string that indicates the source of the file object, of the form `<...>`. This is a read-only attribute and may not be present on all file-like objects.

`file.newlines`

If Python was built with *universal newlines* enabled (the default) this read-only attribute exists, and for files opened in universal newline read mode it keeps track of the types of newlines encountered while reading the file. The values it can take are `'\r'`, `'\n'`, `'\r\n'`, `None` (unknown, no newlines read yet) or a tuple containing all the newline types seen, to indicate that multiple newline conventions were encountered. For files not opened in universal newlines read mode the value of this attribute will be `None`.

`file.softspace`

Boolean that indicates whether a space character needs to be printed before another value when using the `print` statement. Classes that are trying to simulate a file object should also have a writable `softspace` attribute, which should be initialized to zero. This will be automatic for most classes implemented in Python (care may be needed for objects that override attribute access); types implemented in C will have to provide a writable `softspace` attribute.

---

**Note:** This attribute is not used to control the `print` statement, but to allow the implementation of `print` to keep track of its internal state.

---

## 5.10 memoryview type

New in version 2.7. `memoryview` objects allow Python code to access the internal data of an object that supports the buffer protocol without copying. Memory is generally interpreted as simple bytes.

**class `memoryview`** (*obj*)

Create a `memoryview` that references *obj*. *obj* must support the buffer protocol. Built-in objects that support the buffer protocol include `str` and `bytearray` (but not `unicode`).

A `memoryview` has the notion of an *element*, which is the atomic memory unit handled by the originating object *obj*. For many simple types such as `str` and `bytearray`, an element is a single byte, but other third-party types may expose larger elements.

`len(view)` returns the total number of elements in the memoryview, *view*. The `itemsize` attribute will give you the number of bytes in a single element.

A `memoryview` supports slicing to expose its data. Taking a single index will return a single element as a `str` object. Full slicing will result in a subview:

```
>>> v = memoryview('abcefg')
>>> v[1]
'b'
>>> v[-1]
'g'
>>> v[1:4]
<memory at 0x77ab28>
>>> v[1:4].tobytes()
'bce'
```

If the object the memoryview is over supports changing its data, the memoryview supports slice assignment:

```
>>> data = bytearray('abcefg')
>>> v = memoryview(data)
>>> v.readonly
False
>>> v[0] = 'z'
>>> data
bytearray(b'zbcefg')
>>> v[1:4] = '123'
>>> data
bytearray(b'z123fg')
>>> v[2] = 'spam'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot modify size of memoryview object
```

Notice how the size of the memoryview object cannot be changed.

`memoryview` has two methods:

**`tobytes()`**

Return the data in the buffer as a bytestring (an object of class `str`).

```
>>> m = memoryview("abc")
>>> m.tobytes()
'abc'
```

**tolist()**

Return the data in the buffer as a list of integers.

```
>>> memoryview("abc").tolist()
[97, 98, 99]
```

There are also several readonly attributes available:

**format**

A string containing the format (in `struct` module style) for each element in the view. This defaults to `'B'`, a simple bytestring.

**itemsize**

The size in bytes of each element of the memoryview.

**shape**

A tuple of integers the length of `ndim` giving the shape of the memory as a N-dimensional array.

**ndim**

An integer indicating how many dimensions of a multi-dimensional array the memory represents.

**strides**

A tuple of integers the length of `ndim` giving the size in bytes to access each element for each dimension of the array.

**readonly**

A bool indicating whether the memory is read only.

## 5.11 Context Manager Types

New in version 2.5. Python's `with` statement supports the concept of a runtime context defined by a context manager. This is implemented using two separate methods that allow user-defined classes to define a runtime context that is entered before the statement body is executed and exited when the statement ends.

The *context management protocol* consists of a pair of methods that need to be provided for a context manager object to define a runtime context:

`contextmanager.__enter__()`

Enter the runtime context and return either this object or another object related to the runtime context. The value returned by this method is bound to the identifier in the `as` clause of `with` statements using this context manager.

An example of a context manager that returns itself is a file object. File objects return themselves from `__enter__()` to allow `open()` to be used as the context expression in a `with` statement.

An example of a context manager that returns a related object is the one returned by `decimal.localcontext()`. These managers set the active decimal context to a copy of the original decimal context and then return the copy. This allows changes to be made to the current decimal context in the body of the `with` statement without affecting code outside the `with` statement.

`contextmanager.__exit__(exc_type, exc_val, exc_tb)`

Exit the runtime context and return a Boolean flag indicating if any exception that occurred should be suppressed. If an exception occurred while executing the body of the `with` statement, the arguments contain the exception type, value and traceback information. Otherwise, all three arguments are `None`.

Returning a true value from this method will cause the `with` statement to suppress the exception and continue execution with the statement immediately following the `with` statement. Otherwise the exception continues

propagating after this method has finished executing. Exceptions that occur during execution of this method will replace any exception that occurred in the body of the `with` statement.

The exception passed in should never be reraised explicitly - instead, this method should return a false value to indicate that the method completed successfully and does not want to suppress the raised exception. This allows context management code (such as `contextlib.nested`) to easily detect whether or not an `__exit__()` method has actually failed.

Python defines several context managers to support easy thread synchronisation, prompt closure of files or other objects, and simpler manipulation of the active decimal arithmetic context. The specific types are not treated specially beyond their implementation of the context management protocol. See the `contextlib` module for some examples.

Python's *generators* and the `contextlib.contextmanager` *decorator* provide a convenient way to implement these protocols. If a generator function is decorated with the `contextlib.contextmanager` decorator, it will return a context manager implementing the necessary `__enter__()` and `__exit__()` methods, rather than the iterator produced by an undecorated generator function.

Note that there is no specific slot for any of these methods in the type structure for Python objects in the Python/C API. Extension types wanting to define these methods must provide them as a normal Python accessible method. Compared to the overhead of setting up the runtime context, the overhead of a single class dictionary lookup is negligible.

## 5.12 Other Built-in Types

The interpreter supports several other kinds of objects. Most of these support only one or two operations.

### 5.12.1 Modules

The only special operation on a module is attribute access: `m.name`, where `m` is a module and `name` accesses a name defined in `m`'s symbol table. Module attributes can be assigned to. (Note that the `import` statement is not, strictly speaking, an operation on a module object; `import foo` does not require a module object named `foo` to exist, rather it requires an (external) *definition* for a module named `foo` somewhere.)

A special attribute of every module is `__dict__`. This is the dictionary containing the module's symbol table. Modifying this dictionary will actually change the module's symbol table, but direct assignment to the `__dict__` attribute is not possible (you can write `m.__dict__['a'] = 1`, which defines `m.a` to be 1, but you can't write `m.__dict__ = {}`). Modifying `__dict__` directly is not recommended.

Modules built into the interpreter are written like this: `<module 'sys' (built-in)>`. If loaded from a file, they are written as `<module 'os' from '/usr/local/lib/pythonX.Y/os.pyc'>`.

### 5.12.2 Classes and Class Instances

See *objects* and *class* for these.

### 5.12.3 Functions

Function objects are created by function definitions. The only operation on a function object is to call it: `func(argument-list)`.

There are really two flavors of function objects: built-in functions and user-defined functions. Both support the same operation (to call the function), but the implementation is different, hence the different object types.

See *function* for more information.

## 5.12.4 Methods

Methods are functions that are called using the attribute notation. There are two flavors: built-in methods (such as `append()` on lists) and class instance methods. Built-in methods are described with the types that support them.

The implementation adds two special read-only attributes to class instance methods: `m.im_self` is the object on which the method operates, and `m.im_func` is the function implementing the method. Calling `m(arg-1, arg-2, ..., arg-n)` is completely equivalent to calling `m.im_func(m.im_self, arg-1, arg-2, ..., arg-n)`.

Class instance methods are either *bound* or *unbound*, referring to whether the method was accessed through an instance or a class, respectively. When a method is unbound, its `im_self` attribute will be `None` and if called, an explicit `self` object must be passed as the first argument. In this case, `self` must be an instance of the unbound method's class (or a subclass of that class), otherwise a `TypeError` is raised.

Like function objects, methods objects support getting arbitrary attributes. However, since method attributes are actually stored on the underlying function object (`meth.im_func`), setting method attributes on either bound or unbound methods is disallowed. Attempting to set a method attribute results in a `TypeError` being raised. In order to set a method attribute, you need to explicitly set it on the underlying function object:

```
class C:
    def method(self):
        pass

c = C()
c.method.im_func.whoami = 'my name is c'
```

See *types* for more information.

## 5.12.5 Code Objects

Code objects are used by the implementation to represent “pseudo-compiled” executable Python code such as a function body. They differ from function objects because they don't contain a reference to their global execution environment. Code objects are returned by the built-in `compile()` function and can be extracted from function objects through their `func_code` attribute. See also the `code` module.

A code object can be executed or evaluated by passing it (instead of a source string) to the `exec` statement or the built-in `eval()` function.

See *types* for more information.

## 5.12.6 Type Objects

Type objects represent the various object types. An object's type is accessed by the built-in function `type()`. There are no special operations on types. The standard module `types` defines names for all standard built-in types.

Types are written like this: `<type 'int'>`.

## 5.12.7 The Null Object

This object is returned by functions that don't explicitly return a value. It supports no special operations. There is exactly one null object, named `None` (a built-in name).

It is written as `None`.

### 5.12.8 The Ellipsis Object

This object is used by extended slice notation (see *slicings*). It supports no special operations. There is exactly one ellipsis object, named `Ellipsis` (a built-in name).

It is written as `Ellipsis`. When in a subscript, it can also be written as `...`, for example `seq[...]`.

### 5.12.9 The NotImplemented Object

This object is returned from comparisons and binary operations when they are asked to operate on types they don't support. See *comparisons* for more information.

It is written as `NotImplemented`.

### 5.12.10 Boolean Values

Boolean values are the two constant objects `False` and `True`. They are used to represent truth values (although other values can also be considered false or true). In numeric contexts (for example when used as the argument to an arithmetic operator), they behave like the integers 0 and 1, respectively. The built-in function `bool()` can be used to convert any value to a Boolean, if the value can be interpreted as a truth value (see section *Truth Value Testing* above).

They are written as `False` and `True`, respectively.

### 5.12.11 Internal Objects

See *types* for this information. It describes stack frame objects, traceback objects, and slice objects.

## 5.13 Special Attributes

The implementation adds a few special read-only attributes to several object types, where they are relevant. Some of these are not reported by the `dir()` built-in function.

`object.__dict__`

A dictionary or other mapping object used to store an object's (writable) attributes.

`object.__methods__`

Deprecated since version 2.2: Use the built-in function `dir()` to get a list of an object's attributes. This attribute is no longer available.

`object.__members__`

Deprecated since version 2.2: Use the built-in function `dir()` to get a list of an object's attributes. This attribute is no longer available.

`instance.__class__`

The class to which a class instance belongs.

`class.__bases__`

The tuple of base classes of a class object.

`class.__name__`

The name of the class or type.

The following attributes are only supported by *new-style classes*.

class. `__mro__`

This attribute is a tuple of classes that are considered when looking for base classes during method resolution.

class. `mro()`

This method can be overridden by a metaclass to customize the method resolution order for its instances. It is called at class instantiation, and its result is stored in `__mro__`.

class. `__subclasses__()`

Each new-style class keeps a list of weak references to its immediate subclasses. This method returns a list of all those references still alive. Example:

```
>>> int.__subclasses__()
[<type 'bool'>]
```

# BUILT-IN EXCEPTIONS

Exceptions should be class objects. The exceptions are defined in the module `exceptions`. This module never needs to be imported explicitly: the exceptions are provided in the built-in namespace as well as the `exceptions` module.

For class exceptions, in a `try` statement with an `except` clause that mentions a particular class, that clause also handles any exception classes derived from that class (but not exception classes from which *it* is derived). Two exception classes that are not related via subclassing are never equivalent, even if they have the same name.

The built-in exceptions listed below can be generated by the interpreter or built-in functions. Except where mentioned, they have an “associated value” indicating the detailed cause of the error. This may be a string or a tuple containing several items of information (e.g., an error code and a string explaining the code). The associated value is the second argument to the `raise` statement. If the exception class is derived from the standard root class `BaseException`, the associated value is present as the exception instance’s `args` attribute.

User code can raise built-in exceptions. This can be used to test an exception handler or to report an error condition “just like” the situation in which the interpreter raises the same exception; but beware that there is nothing to prevent user code from raising an inappropriate error.

The built-in exception classes can be sub-classed to define new exceptions; programmers are encouraged to at least derive new exceptions from the `Exception` class and not `BaseException`. More information on defining exceptions is available in the Python Tutorial under *tut-userexceptions*.

The following exceptions are only used as base classes for other exceptions.

## exception `BaseException`

The base class for all built-in exceptions. It is not meant to be directly inherited by user-defined classes (for that, use `Exception`). If `str()` or `unicode()` is called on an instance of this class, the representation of the argument(s) to the instance are returned, or the empty string when there were no arguments. New in version 2.5.

### `args`

The tuple of arguments given to the exception constructor. Some built-in exceptions (like `IOError`) expect a certain number of arguments and assign a special meaning to the elements of this tuple, while others are usually called only with a single string giving an error message.

## exception `Exception`

All built-in, non-system-exiting exceptions are derived from this class. All user-defined exceptions should also be derived from this class. Changed in version 2.5: Changed to inherit from `BaseException`.

## exception `StandardError`

The base class for all built-in exceptions except `StopIteration`, `GeneratorExit`, `KeyboardInterrupt` and `SystemExit`. `StandardError` itself is derived from `Exception`.

### exception `ArithmeticError`

The base class for those built-in exceptions that are raised for various arithmetic errors: `OverflowError`, `ZeroDivisionError`, `FloatingPointError`.

### exception `BufferError`

Raised when a *buffer* related operation cannot be performed.

### exception `LookupError`

The base class for the exceptions that are raised when a key or index used on a mapping or sequence is invalid: `IndexError`, `KeyError`. This can be raised directly by `codecs.lookup()`.

### exception `EnvironmentError`

The base class for exceptions that can occur outside the Python system: `IOError`, `OSError`. When exceptions of this type are created with a 2-tuple, the first item is available on the instance's `errno` attribute (it is assumed to be an error number), and the second item is available on the `strerror` attribute (it is usually the associated error message). The tuple itself is also available on the `args` attribute. New in version 1.5.2. When an `EnvironmentError` exception is instantiated with a 3-tuple, the first two items are available as above, while the third item is available on the `filename` attribute. However, for backwards compatibility, the `args` attribute contains only a 2-tuple of the first two constructor arguments.

The `filename` attribute is `None` when this exception is created with other than 3 arguments. The `errno` and `strerror` attributes are also `None` when the instance was created with other than 2 or 3 arguments. In this last case, `args` contains the verbatim constructor arguments as a tuple.

The following exceptions are the exceptions that are actually raised.

### exception `AssertionError`

Raised when an `assert` statement fails.

### exception `AttributeError`

Raised when an attribute reference (see *attribute-references*) or assignment fails. (When an object does not support attribute references or attribute assignments at all, `TypeError` is raised.)

### exception `EOFError`

Raised when one of the built-in functions (`input()` or `raw_input()`) hits an end-of-file condition (EOF) without reading any data. (N.B.: the `file.read()` and `file.readline()` methods return an empty string when they hit EOF.)

### exception `FloatingPointError`

Raised when a floating point operation fails. This exception is always defined, but can only be raised when Python is configured with the `--with-fpectl` option, or the `WANT_SIGFPE_HANDLER` symbol is defined in the `pyconfig.h` file.

### exception `GeneratorExit`

Raise when a *generator*'s `close()` method is called. It directly inherits from `BaseException` instead of `StandardError` since it is technically not an error. New in version 2.5. Changed in version 2.6: Changed to inherit from `BaseException`.

### exception `IOError`

Raised when an I/O operation (such as a `print` statement, the built-in `open()` function or a method of a file object) fails for an I/O-related reason, e.g., "file not found" or "disk full".

This class is derived from `EnvironmentError`. See the discussion above for more information on exception instance attributes. Changed in version 2.6: Changed `socket.error` to use this as a base class.

### exception `ImportError`

Raised when an `import` statement fails to find the module definition or when a `from ... import` fails to find a name that is to be imported.

**exception IndexError**

Raised when a sequence subscript is out of range. (Slice indices are silently truncated to fall in the allowed range; if an index is not a plain integer, `TypeError` is raised.)

**exception KeyError**

Raised when a mapping (dictionary) key is not found in the set of existing keys.

**exception KeyboardInterrupt**

Raised when the user hits the interrupt key (normally `Control-C` or `Delete`). During execution, a check for interrupts is made regularly. Interrupts typed when a built-in function `input()` or `raw_input()` is waiting for input also raise this exception. The exception inherits from `BaseException` so as to not be accidentally caught by code that catches `Exception` and thus prevent the interpreter from exiting. Changed in version 2.5: Changed to inherit from `BaseException`.

**exception MemoryError**

Raised when an operation runs out of memory but the situation may still be rescued (by deleting some objects). The associated value is a string indicating what kind of (internal) operation ran out of memory. Note that because of the underlying memory management architecture (C's `malloc()` function), the interpreter may not always be able to completely recover from this situation; it nevertheless raises an exception so that a stack traceback can be printed, in case a run-away program was the cause.

**exception NameError**

Raised when a local or global name is not found. This applies only to unqualified names. The associated value is an error message that includes the name that could not be found.

**exception NotImplementedError**

This exception is derived from `RuntimeError`. In user defined base classes, abstract methods should raise this exception when they require derived classes to override the method. New in version 1.5.2.

**exception OSError**

This exception is derived from `EnvironmentError`. It is raised when a function returns a system-related error (not for illegal argument types or other incidental errors). The `errno` attribute is a numeric error code from `errno`, and the `strerror` attribute is the corresponding string, as would be printed by the C function `perror()`. See the module `errno`, which contains names for the error codes defined by the underlying operating system.

For exceptions that involve a file system path (such as `chdir()` or `unlink()`), the exception instance will contain a third attribute, `filename`, which is the file name passed to the function. New in version 1.5.2.

**exception OverflowError**

Raised when the result of an arithmetic operation is too large to be represented. This cannot occur for long integers (which would rather raise `MemoryError` than give up) and for most operations with plain integers, which return a long integer instead. Because of the lack of standardization of floating point exception handling in C, most floating point operations also aren't checked.

**exception ReferenceError**

This exception is raised when a weak reference proxy, created by the `weakref.proxy()` function, is used to access an attribute of the referent after it has been garbage collected. For more information on weak references, see the `weakref` module. New in version 2.2: Previously known as the `weakref.ReferenceError` exception.

**exception RuntimeError**

Raised when an error is detected that doesn't fall in any of the other categories. The associated value is a string indicating what precisely went wrong. (This exception is mostly a relic from a previous version of the interpreter; it is not used very much any more.)

**exception StopIteration**

Raised by an `iterator`'s `next()` method to signal that there are no further values. This is derived from

`Exception` rather than `StandardError`, since this is not considered an error in its normal application. New in version 2.2.

### exception `SyntaxError`

Raised when the parser encounters a syntax error. This may occur in an `import` statement, in an `exec` statement, in a call to the built-in function `eval()` or `input()`, or when reading the initial script or standard input (also interactively).

Instances of this class have attributes `filename`, `lineno`, `offset` and `text` for easier access to the details. `str()` of the exception instance returns only the message.

### exception `IndentationError`

Base class for syntax errors related to incorrect indentation. This is a subclass of `SyntaxError`.

### exception `TabError`

Raised when indentation contains an inconsistent use of tabs and spaces. This is a subclass of `IndentationError`.

### exception `SystemError`

Raised when the interpreter finds an internal error, but the situation does not look so serious to cause it to abandon all hope. The associated value is a string indicating what went wrong (in low-level terms).

You should report this to the author or maintainer of your Python interpreter. Be sure to report the version of the Python interpreter (`sys.version`; it is also printed at the start of an interactive Python session), the exact error message (the exception's associated value) and if possible the source of the program that triggered the error.

### exception `SystemExit`

This exception is raised by the `sys.exit()` function. When it is not handled, the Python interpreter exits; no stack traceback is printed. If the associated value is a plain integer, it specifies the system exit status (passed to C's `exit()` function); if it is `None`, the exit status is zero; if it has another type (such as a string), the object's value is printed and the exit status is one.

Instances have an attribute `code` which is set to the proposed exit status or error message (defaulting to `None`). Also, this exception derives directly from `BaseException` and not `StandardError`, since it is not technically an error.

A call to `sys.exit()` is translated into an exception so that clean-up handlers (`finally` clauses of `try` statements) can be executed, and so that a debugger can execute a script without running the risk of losing control. The `os._exit()` function can be used if it is absolutely positively necessary to exit immediately (for example, in the child process after a call to `fork()`).

The exception inherits from `BaseException` instead of `StandardError` or `Exception` so that it is not accidentally caught by code that catches `Exception`. This allows the exception to properly propagate up and cause the interpreter to exit. Changed in version 2.5: Changed to inherit from `BaseException`.

### exception `TypeError`

Raised when an operation or function is applied to an object of inappropriate type. The associated value is a string giving details about the type mismatch.

### exception `UnboundLocalError`

Raised when a reference is made to a local variable in a function or method, but no value has been bound to that variable. This is a subclass of `NameError`. New in version 2.0.

### exception `UnicodeError`

Raised when a Unicode-related encoding or decoding error occurs. It is a subclass of `ValueError`. New in version 2.0.

### exception `UnicodeEncodeError`

Raised when a Unicode-related error occurs during encoding. It is a subclass of `UnicodeError`. New in version 2.3.

**exception UnicodeDecodeError**

Raised when a Unicode-related error occurs during decoding. It is a subclass of `UnicodeError`. New in version 2.3.

**exception UnicodeTranslateError**

Raised when a Unicode-related error occurs during translating. It is a subclass of `UnicodeError`. New in version 2.3.

**exception ValueError**

Raised when a built-in operation or function receives an argument that has the right type but an inappropriate value, and the situation is not described by a more precise exception such as `IndexError`.

**exception VMSError**

Only available on VMS. Raised when a VMS-specific error occurs.

**exception WindowsError**

Raised when a Windows-specific error occurs or when the error number does not correspond to an `errno` value. The `winerror` and `strerror` values are created from the return values of the `GetLastError()` and `FormatMessage()` functions from the Windows Platform API. The `errno` value maps the `winerror` value to corresponding `errno.h` values. This is a subclass of `OSError`. New in version 2.0. Changed in version 2.5: Previous versions put the `GetLastError()` codes into `errno`.

**exception ZeroDivisionError**

Raised when the second argument of a division or modulo operation is zero. The associated value is a string indicating the type of the operands and the operation.

The following exceptions are used as warning categories; see the `warnings` module for more information.

**exception Warning**

Base class for warning categories.

**exception UserWarning**

Base class for warnings generated by user code.

**exception DeprecationWarning**

Base class for warnings about deprecated features.

**exception PendingDeprecationWarning**

Base class for warnings about features which will be deprecated in the future.

**exception SyntaxWarning**

Base class for warnings about dubious syntax

**exception RuntimeWarning**

Base class for warnings about dubious runtime behavior.

**exception FutureWarning**

Base class for warnings about constructs that will change semantically in the future.

**exception ImportWarning**

Base class for warnings about probable mistakes in module imports. New in version 2.5.

**exception UnicodeWarning**

Base class for warnings related to Unicode. New in version 2.5.

## 6.1 Exception hierarchy

The class hierarchy for built-in exceptions is:

```
BaseException
+-- SystemExit
+-- KeyboardInterrupt
+-- GeneratorExit
+-- Exception
    +-- StopIteration
+-- StandardError
    | +-- BufferError
    | +-- ArithmeticError
    | | +-- FloatingPointError
    | | +-- OverflowError
    | | +-- ZeroDivisionError
    | +-- AssertionError
    | +-- AttributeError
    | +-- EnvironmentError
    | | +-- IOError
    | | +-- OSError
    | | +-- WindowsError (Windows)
    | | +-- VMSError (VMS)
    | +-- EOFError
    | +-- ImportError
    | +-- LookupError
    | | +-- IndexError
    | | +-- KeyError
    | +-- MemoryError
    | +-- NameError
    | | +-- UnboundLocalError
    | +-- ReferenceError
    | +-- RuntimeError
    | | +-- NotImplementedError
    | +-- SyntaxError
    | | +-- IndentationError
    | | +-- TabError
    | +-- SystemError
    | +-- TypeError
    | +-- ValueError
    | | +-- UnicodeError
    | | | +-- UnicodeDecodeError
    | | | +-- UnicodeEncodeError
    | | | +-- UnicodeTranslateError
+-- Warning
    +-- DeprecationWarning
    +-- PendingDeprecationWarning
    +-- RuntimeWarning
    +-- SyntaxWarning
    +-- UserWarning
    +-- FutureWarning
    +-- ImportWarning
    +-- UnicodeWarning
    +-- BytesWarning
```

# STRING SERVICES

The modules described in this chapter provide a wide range of string manipulation operations.

In addition, Python's built-in string classes support the sequence type methods described in the *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange* section, and also the string-specific methods described in the *String Methods* section. To output formatted strings use template strings or the % operator described in the *String Formatting Operations* section. Also, see the `re` module for string functions based on regular expressions.

## 7.1 string — Common string operations

**Source code:** `Lib/string.py`

---

The `string` module contains a number of useful constants and classes, as well as some deprecated legacy functions that are also available as methods on strings. In addition, Python's built-in string classes support the sequence type methods described in the *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange* section, and also the string-specific methods described in the *String Methods* section. To output formatted strings use template strings or the % operator described in the *String Formatting Operations* section. Also, see the `re` module for string functions based on regular expressions.

### 7.1.1 String constants

The constants defined in this module are:

`string.ascii_letters`

The concatenation of the `ascii_lowercase` and `ascii_uppercase` constants described below. This value is not locale-dependent.

`string.ascii_lowercase`

The lowercase letters `'abcdefghijklmnopqrstuvwxyz'`. This value is not locale-dependent and will not change.

`string.ascii_uppercase`

The uppercase letters `'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. This value is not locale-dependent and will not change.

`string.digits`

The string `'0123456789'`.

`string.hexdigits`

The string `'0123456789abcdefABCDEF'`.

### `string.letters`

The concatenation of the strings `lowercase` and `uppercase` described below. The specific value is locale-dependent, and will be updated when `locale.setlocale()` is called.

### `string.lowercase`

A string containing all the characters that are considered lowercase letters. On most systems this is the string `'abcdefghijklmnopqrstuvwxyz'`. The specific value is locale-dependent, and will be updated when `locale.setlocale()` is called.

### `string.octdigits`

The string `'01234567'`.

### `string.punctuation`

String of ASCII characters which are considered punctuation characters in the C locale.

### `string.printable`

String of characters which are considered printable. This is a combination of `digits`, `letters`, `punctuation`, and `whitespace`.

### `string.uppercase`

A string containing all the characters that are considered uppercase letters. On most systems this is the string `'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. The specific value is locale-dependent, and will be updated when `locale.setlocale()` is called.

### `string.whitespace`

A string containing all characters that are considered whitespace. On most systems this includes the characters space, tab, linefeed, return, formfeed, and vertical tab.

## 7.1.2 String Formatting

New in version 2.6. The built-in `str` and `unicode` classes provide the ability to do complex variable substitutions and value formatting via the `str.format()` method described in [PEP 3101](#). The `Formatter` class in the `string` module allows you to create and customize your own string formatting behaviors using the same implementation as the built-in `format()` method.

### `class string.Formatter`

The `Formatter` class has the following public methods:

#### `format` (*format\_string*, \**args*, \*\**kwargs*)

`format()` is the primary API method. It takes a format string and an arbitrary set of positional and keyword arguments. `format()` is just a wrapper that calls `vformat()`.

#### `vformat` (*format\_string*, *args*, *kwargs*)

This function does the actual work of formatting. It is exposed as a separate function for cases where you want to pass in a predefined dictionary of arguments, rather than unpacking and repacking the dictionary as individual arguments using the `*args` and `**kwargs` syntax. `vformat()` does the work of breaking up the format string into character data and replacement fields. It calls the various methods described below.

In addition, the `Formatter` defines a number of methods that are intended to be replaced by subclasses:

#### `parse` (*format\_string*)

Loop over the `format_string` and return an iterable of tuples (*literal\_text*, *field\_name*, *format\_spec*, *conversion*). This is used by `vformat()` to break the string into either literal text, or replacement fields.

The values in the tuple conceptually represent a span of literal text followed by a single replacement field. If there is no literal text (which can happen if two replacement fields occur consecutively), then *literal\_text* will be a zero-length string. If there is no replacement field, then the values of *field\_name*, *format\_spec* and *conversion* will be `None`.

**get\_field** (*field\_name*, *args*, *kwargs*)

Given *field\_name* as returned by `parse()` (see above), convert it to an object to be formatted. Returns a tuple (obj, used\_key). The default version takes strings of the form defined in **PEP 3101**, such as “0[name]” or “label.title”. *args* and *kwargs* are as passed in to `vformat()`. The return value *used\_key* has the same meaning as the *key* parameter to `get_value()`.

**get\_value** (*key*, *args*, *kwargs*)

Retrieve a given field value. The *key* argument will be either an integer or a string. If it is an integer, it represents the index of the positional argument in *args*; if it is a string, then it represents a named argument in *kwargs*.

The *args* parameter is set to the list of positional arguments to `vformat()`, and the *kwargs* parameter is set to the dictionary of keyword arguments.

For compound field names, these functions are only called for the first component of the field name; Subsequent components are handled through normal attribute and indexing operations.

So for example, the field expression ‘0.name’ would cause `get_value()` to be called with a *key* argument of 0. The `name` attribute will be looked up after `get_value()` returns by calling the built-in `getattr()` function.

If the index or keyword refers to an item that does not exist, then an `IndexError` or `KeyError` should be raised.

**check\_unused\_args** (*used\_args*, *args*, *kwargs*)

Implement checking for unused arguments if desired. The arguments to this function is the set of all argument keys that were actually referred to in the format string (integers for positional arguments, and strings for named arguments), and a reference to the *args* and *kwargs* that was passed to `vformat`. The set of unused args can be calculated from these parameters. `check_unused_args()` is assumed to raise an exception if the check fails.

**format\_field** (*value*, *format\_spec*)

`format_field()` simply calls the global `format()` built-in. The method is provided so that subclasses can override it.

**convert\_field** (*value*, *conversion*)

Converts the value (returned by `get_field()`) given a conversion type (as in the tuple returned by the `parse()` method). The default version understands ‘s’ (str), ‘r’ (repr) and ‘a’ (ascii) conversion types.

### 7.1.3 Format String Syntax

The `str.format()` method and the `Formatter` class share the same syntax for format strings (although in the case of `Formatter`, subclasses can define their own format string syntax).

Format strings contain “replacement fields” surrounded by curly braces `{}`. Anything that is not contained in braces is considered literal text, which is copied unchanged to the output. If you need to include a brace character in the literal text, it can be escaped by doubling: `{{` and `}}`.

The grammar for a replacement field is as follows:

```
replacement_field ::= "{" [field_name] ["!" conversion] [":" format_spec] "}"
field_name        ::= arg_name ("." attribute_name | "[" element_index "]")*
arg_name          ::= [identifier | integer]
attribute_name    ::= identifier
element_index     ::= integer | index_string
index_string      ::= <any source character except "]"> +
conversion        ::= "r" | "s"
format_spec       ::= <described in the next section>
```

In less formal terms, the replacement field can start with a *field\_name* that specifies the object whose value is to be formatted and inserted into the output instead of the replacement field. The *field\_name* is optionally followed by a *conversion* field, which is preceded by an exclamation point '!', and a *format\_spec*, which is preceded by a colon ':'. These specify a non-default format for the replacement value.

See also the *Format Specification Mini-Language* section.

The *field\_name* itself begins with an *arg\_name* that is either a number or a keyword. If it's a number, it refers to a positional argument, and if it's a keyword, it refers to a named keyword argument. If the numerical *arg\_names* in a format string are 0, 1, 2, ... in sequence, they can all be omitted (not just some) and the numbers 0, 1, 2, ... will be automatically inserted in that order. Because *arg\_name* is not quote-delimited, it is not possible to specify arbitrary dictionary keys (e.g., the strings '10' or ':-}') within a format string. The *arg\_name* can be followed by any number of index or attribute expressions. An expression of the form '.name' selects the named attribute using `getattr()`, while an expression of the form '[index]' does an index lookup using `__getitem__()`. Changed in version 2.7: The positional argument specifiers can be omitted, so '{} {}' is equivalent to '{0} {1}'. Some simple format string examples:

```
"First, thou shalt count to {0}" # References first positional argument
"Bring me a {}"                # Implicitly references the first positional argument
"From {} to {}"                # Same as "From {0} to {1}"
"My quest is {name}"           # References keyword argument 'name'
"Weight in tons {0.weight}"    # 'weight' attribute of first positional arg
"Units destroyed: {players[0]}" # First element of keyword argument 'players'.
```

The *conversion* field causes a type coercion before formatting. Normally, the job of formatting a value is done by the `__format__()` method of the value itself. However, in some cases it is desirable to force a type to be formatted as a string, overriding its own definition of formatting. By converting the value to a string before calling `__format__()`, the normal formatting logic is bypassed.

Two conversion flags are currently supported: '!'s' which calls `str()` on the value, and '!r' which calls `repr()`.

Some examples:

```
"Harold's a clever {0!s}"      # Calls str() on the argument first
"Bring out the holy {name!r}"  # Calls repr() on the argument first
```

The *format\_spec* field contains a specification of how the value should be presented, including such details as field width, alignment, padding, decimal precision and so on. Each value type can define its own "formatting mini-language" or interpretation of the *format\_spec*.

Most built-in types support a common formatting mini-language, which is described in the next section.

A *format\_spec* field can also include nested replacement fields within it. These nested replacement fields can contain only a field name; conversion flags and format specifications are not allowed. The replacement fields within the *format\_spec* are substituted before the *format\_spec* string is interpreted. This allows the formatting of a value to be dynamically specified.

See the *Format examples* section for some examples.

### Format Specification Mini-Language

"Format specifications" are used within replacement fields contained within a format string to define how individual values are presented (see *Format String Syntax*). They can also be passed directly to the built-in `format()` function. Each formattable type may define how the format specification is to be interpreted.

Most built-in types implement the following options for format specifications, although some of the formatting options are only supported by the numeric types.

A general convention is that an empty format string ("") produces the same result as if you had called `str()` on the value. A non-empty format string typically modifies the result.

The general form of a *standard format specifier* is:

```
format_spec ::= [[fill]align][sign][#][0][width][,][.precision][type]
fill        ::= <a character other than ` ` or ` `>
align       ::= "<" | ">" | "=" | "^"
sign        ::= "+" | "-" | " "
width       ::= integer
precision   ::= integer
type        ::= "b" | "c" | "d" | "e" | "E" | "f" | "F" | "g" | "G" | "n" | "o" | "s"
```

The *fill* character can be any character other than `' '` or `' '`. The presence of a fill character is signaled by the character following it, which must be one of the alignment options. If the second character of *format\_spec* is not a valid alignment option, then it is assumed that both the fill character and the alignment option are absent.

The meaning of the various alignment options is as follows:

Op-tion	Meaning
'<'	Forces the field to be left-aligned within the available space (this is the default for most objects).
'>'	Forces the field to be right-aligned within the available space (this is the default for numbers).
'='	Forces the padding to be placed after the sign (if any) but before the digits. This is used for printing fields in the form <code>'+000000120'</code> . This alignment option is only valid for numeric types.
'^'	Forces the field to be centered within the available space.

Note that unless a minimum field width is defined, the field width will always be the same size as the data to fill it, so that the alignment option has no meaning in this case.

The *sign* option is only valid for number types, and can be one of the following:

Op-tion	Meaning
'+'	indicates that a sign should be used for both positive as well as negative numbers.
'-'	indicates that a sign should be used only for negative numbers (this is the default behavior).
space	indicates that a leading space should be used on positive numbers, and a minus sign on negative numbers.

The `'#'` option is only valid for integers, and only for binary, octal, or hexadecimal output. If present, it specifies that the output will be prefixed by `'0b'`, `'0o'`, or `'0x'`, respectively.

The `','` option signals the use of a comma for a thousands separator. For a locale aware separator, use the `'n'` integer presentation type instead. Changed in version 2.7: Added the `','` option (see also [PEP 378](#)). *width* is a decimal integer defining the minimum field width. If not specified, then the field width will be determined by the content.

Preceding the *width* field by a zero (`'0'`) character enables sign-aware zero-padding for numeric types. This is equivalent to a *fill* character of `'0'` with an *alignment* type of `'=''`.

The *precision* is a decimal number indicating how many digits should be displayed after the decimal point for a floating point value formatted with `'f'` and `'F'`, or before and after the decimal point for a floating point value formatted with `'g'` or `'G'`. For non-number types the field indicates the maximum field size - in other words, how many characters will be used from the field content. The *precision* is not allowed for integer values.

Finally, the *type* determines how the data should be presented.

The available string presentation types are:

Type	Meaning
's'	String format. This is the default type for strings and may be omitted.
None	The same as 's'.

The available integer presentation types are:

Type	Meaning
'b'	Binary format. Outputs the number in base 2.
'c'	Character. Converts the integer to the corresponding unicode character before printing.
'd'	Decimal Integer. Outputs the number in base 10.
'o'	Octal format. Outputs the number in base 8.
'x'	Hex format. Outputs the number in base 16, using lower- case letters for the digits above 9.
'X'	Hex format. Outputs the number in base 16, using upper- case letters for the digits above 9.
'n'	Number. This is the same as 'd', except that it uses the current locale setting to insert the appropriate number separator characters.
None	The same as 'd'.

In addition to the above presentation types, integers can be formatted with the floating point presentation types listed below (except 'n' and None). When doing so, `float()` is used to convert the integer to a floating point number before formatting.

The available presentation types for floating point and decimal values are:

Type	Meaning
'e'	Exponent notation. Prints the number in scientific notation using the letter 'e' to indicate the exponent.
'E'	Exponent notation. Same as 'e' except it uses an upper case 'E' as the separator character.
'f'	Fixed point. Displays the number as a fixed-point number.
'F'	Fixed point. Same as 'f'.
'g'	General format. For a given precision $p \geq 1$ , this rounds the number to $p$ significant digits and then formats the result in either fixed-point format or in scientific notation, depending on its magnitude. The precise rules are as follows: suppose that the result formatted with presentation type 'e' and precision $p-1$ would have exponent $exp$ . Then if $-4 \leq exp < p$ , the number is formatted with presentation type 'f' and precision $p-1-exp$ . Otherwise, the number is formatted with presentation type 'e' and precision $p-1$ . In both cases insignificant trailing zeros are removed from the significand, and the decimal point is also removed if there are no remaining digits following it. Positive and negative infinity, positive and negative zero, and nans, are formatted as <code>inf</code> , <code>-inf</code> , <code>0</code> , <code>-0</code> and <code>nan</code> respectively, regardless of the precision. A precision of 0 is treated as equivalent to a precision of 1.
'G'	General format. Same as 'g' except switches to 'E' if the number gets too large. The representations of infinity and NaN are uppercased, too.
'n'	Number. This is the same as 'g', except that it uses the current locale setting to insert the appropriate number separator characters.
'%'	Percentage. Multiplies the number by 100 and displays in fixed ('f') format, followed by a percent sign.
None	The same as 'g'.

## Format examples

This section contains examples of the new format syntax and comparison with the old %-formatting.

In most of the cases the syntax is similar to the old %-formatting, with the addition of the `{}` and with `:` used instead of `%`. For example, `'%03.2f'` can be translated to `'{:03.2f}'`.

The new format syntax also supports new and different options, shown in the follow examples.

Accessing arguments by position:

```
>>> '{0}, {1}, {2}'.format('a', 'b', 'c')
'a, b, c'
>>> '{}', {}, {}'.format('a', 'b', 'c') # 2.7+ only
'a, b, c'
>>> '{2}, {1}, {0}'.format('a', 'b', 'c')
'c, b, a'
>>> '{2}, {1}, {0}'.format(*'abc') # unpacking argument sequence
'c, b, a'
>>> '{0}{1}{0}'.format('abra', 'cad') # arguments' indices can be repeated
'abracadabra'
```

Accessing arguments by name:

```
>>> 'Coordinates: {latitude}, {longitude}'.format(latitude='37.24N', longitude='-115.81W')
'Coordinates: 37.24N, -115.81W'
>>> coord = {'latitude': '37.24N', 'longitude': '-115.81W'}
>>> 'Coordinates: {latitude}, {longitude}'.format(**coord)
'Coordinates: 37.24N, -115.81W'
```

Accessing arguments' attributes:

```
>>> c = 3-5j
>>> ('The complex number {0} is formed from the real part {0.real} '
... 'and the imaginary part {0.imag}.').format(c)
'The complex number (3-5j) is formed from the real part 3.0 and the imaginary part -5.0.'
>>> class Point(object):
...     def __init__(self, x, y):
...         self.x, self.y = x, y
...     def __str__(self):
...         return 'Point({self.x}, {self.y})'.format(self=self)
...
>>> str(Point(4, 2))
'Point(4, 2)'
```

Accessing arguments' items:

```
>>> coord = (3, 5)
>>> 'X: {0[0]}; Y: {0[1]}'.format(coord)
'X: 3; Y: 5'
```

Replacing %s and %r:

```
>>> "repr() shows quotes: {!r}; str() doesn't: {!s}".format('test1', 'test2')
'repr() shows quotes: 'test1'; str() doesn't: test2'
```

Aligning the text and specifying a width:

```
>>> '{:<30}'.format('left aligned')
'left aligned'
>>> '{:>30}'.format('right aligned')
'right aligned'
>>> '{:^30}'.format('centered')
'centered'
>>> '{:*^30}'.format('centered') # use '*' as a fill char
'*****centered*****'
```



6	6	6	110
7	7	7	111
8	8	10	1000
9	9	11	1001
10	A	12	1010
11	B	13	1011

### 7.1.4 Template strings

New in version 2.4. Templates provide simpler string substitutions as described in [PEP 292](#). Instead of the normal %-based substitutions, Templates support \$-based substitutions, using the following rules:

- `$$` is an escape; it is replaced with a single `$`.
- `$identifier` names a substitution placeholder matching a mapping key of "identifier". By default, "identifier" must spell a Python identifier. The first non-identifier character after the `$` character terminates this placeholder specification.
- `${identifier}` is equivalent to `$identifier`. It is required when valid identifier characters follow the placeholder but are not part of the placeholder, such as "`${noun}ification`".

Any other appearance of `$` in the string will result in a `ValueError` being raised.

The `string` module provides a `Template` class that implements these rules. The methods of `Template` are:

**class** `string.Template` (*template*)

The constructor takes a single argument which is the template string.

**substitute** (*mapping* [, *\*\*kws* ])

Performs the template substitution, returning a new string. *mapping* is any dictionary-like object with keys that match the placeholders in the template. Alternatively, you can provide keyword arguments, where the keywords are the placeholders. When both *mapping* and *kws* are given and there are duplicates, the placeholders from *kws* take precedence.

**safe\_substitute** (*mapping* [, *\*\*kws* ])

Like `substitute()`, except that if placeholders are missing from *mapping* and *kws*, instead of raising a `KeyError` exception, the original placeholder will appear in the resulting string intact. Also, unlike with `substitute()`, any other appearances of the `$` will simply return `$` instead of raising `ValueError`.

While other exceptions may still occur, this method is called “safe” because substitutions always tries to return a usable string instead of raising an exception. In another sense, `safe_substitute()` may be anything other than safe, since it will silently ignore malformed templates containing dangling delimiters, unmatched braces, or placeholders that are not valid Python identifiers.

`Template` instances also provide one public data attribute:

**template**

This is the object passed to the constructor’s *template* argument. In general, you shouldn’t change it, but read-only access is not enforced.

Here is an example of how to use a `Template`:

```
>>> from string import Template
>>> s = Template('$who likes $what')
>>> s.substitute(who='tim', what='kung pao')
'tim likes kung pao'
>>> d = dict(who='tim')
>>> Template('Give $who $100').substitute(d)
Traceback (most recent call last):
[...]
```

```
ValueError: Invalid placeholder in string: line 1, col 10
>>> Template('$who likes $what').substitute(d)
Traceback (most recent call last):
[...]
KeyError: 'what'
>>> Template('$who likes $what').safe_substitute(d)
'tim likes $what'
```

Advanced usage: you can derive subclasses of `Template` to customize the placeholder syntax, delimiter character, or the entire regular expression used to parse template strings. To do this, you can override these class attributes:

- *delimiter* – This is the literal string describing a placeholder introducing delimiter. The default value is `$`. Note that this should *not* be a regular expression, as the implementation will call `re.escape()` on this string as needed.
- *idpattern* – This is the regular expression describing the pattern for non-braced placeholders (the braces will be added automatically as appropriate). The default value is the regular expression `[_a-z][_a-z0-9]*`.

Alternatively, you can provide the entire regular expression pattern by overriding the class attribute *pattern*. If you do this, the value must be a regular expression object with four named capturing groups. The capturing groups correspond to the rules given above, along with the invalid placeholder rule:

- *escaped* – This group matches the escape sequence, e.g. `$$`, in the default pattern.
- *named* – This group matches the unbraced placeholder name; it should not include the delimiter in capturing group.
- *braced* – This group matches the brace enclosed placeholder name; it should not include either the delimiter or braces in the capturing group.
- *invalid* – This group matches any other delimiter pattern (usually a single delimiter), and it should appear last in the regular expression.

### 7.1.5 String functions

The following functions are available to operate on string and Unicode objects. They are not available as string methods.

`string.capwords(s[, sep])`

Split the argument into words using `str.split()`, capitalize each word using `str.capitalize()`, and join the capitalized words using `str.join()`. If the optional second argument *sep* is absent or `None`, runs of whitespace characters are replaced by a single space and leading and trailing whitespace are removed, otherwise *sep* is used to split and join the words.

`string.maketrans(from, to)`

Return a translation table suitable for passing to `translate()`, that will map each character in *from* into the character at the same position in *to*; *from* and *to* must have the same length.

---

**Note:** Don't use strings derived from `lowercase` and `uppercase` as arguments; in some locales, these don't have the same length. For case conversions, always use `str.lower()` and `str.upper()`.

---

### 7.1.6 Deprecated string functions

The following list of functions are also defined as methods of string and Unicode objects; see section *String Methods* for more information on those. You should consider these functions as deprecated, although they will not be removed until Python 3. The functions defined in this module are:

`string.atof(s)`

Deprecated since version 2.0: Use the `float()` built-in function. Convert a string to a floating point number. The string must have the standard syntax for a floating point literal in Python, optionally preceded by a sign (+ or -). Note that this behaves identical to the built-in function `float()` when passed a string.

---

**Note:** When passing in a string, values for NaN and Infinity may be returned, depending on the underlying C library. The specific set of strings accepted which cause these values to be returned depends entirely on the C library and is known to vary.

---

`string.atoi(s[, base])`

Deprecated since version 2.0: Use the `int()` built-in function. Convert string `s` to an integer in the given `base`. The string must consist of one or more digits, optionally preceded by a sign (+ or -). The `base` defaults to 10. If it is 0, a default base is chosen depending on the leading characters of the string (after stripping the sign): `0x` or `0X` means 16, `0` means 8, anything else means 10. If `base` is 16, a leading `0x` or `0X` is always accepted, though not required. This behaves identically to the built-in function `int()` when passed a string. (Also note: for a more flexible interpretation of numeric literals, use the built-in function `eval()`.)

`string.atol(s[, base])`

Deprecated since version 2.0: Use the `long()` built-in function. Convert string `s` to a long integer in the given `base`. The string must consist of one or more digits, optionally preceded by a sign (+ or -). The `base` argument has the same meaning as for `atoi()`. A trailing `l` or `L` is not allowed, except if the base is 0. Note that when invoked without `base` or with `base` set to 10, this behaves identical to the built-in function `long()` when passed a string.

`string.capitalize(word)`

Return a copy of `word` with only its first character capitalized.

`string.expandtabs(s[, tabsize])`

Expand tabs in a string replacing them by one or more spaces, depending on the current column and the given tab size. The column number is reset to zero after each newline occurring in the string. This doesn't understand other non-printing characters or escape sequences. The tab size defaults to 8.

`string.find(s, sub[, start[, end]])`

Return the lowest index in `s` where the substring `sub` is found such that `sub` is wholly contained in `s[start:end]`. Return -1 on failure. Defaults for `start` and `end` and interpretation of negative values is the same as for slices.

`string.rfind(s, sub[, start[, end]])`

Like `find()` but find the highest index.

`string.index(s, sub[, start[, end]])`

Like `find()` but raise `ValueError` when the substring is not found.

`string.rindex(s, sub[, start[, end]])`

Like `rfind()` but raise `ValueError` when the substring is not found.

`string.count(s, sub[, start[, end]])`

Return the number of (non-overlapping) occurrences of substring `sub` in string `s[start:end]`. Defaults for `start` and `end` and interpretation of negative values are the same as for slices.

`string.lower(s)`

Return a copy of `s`, but with upper case letters converted to lower case.

`string.split(s[, sep[, maxsplit]])`

Return a list of the words of the string `s`. If the optional second argument `sep` is absent or `None`, the words are separated by arbitrary strings of whitespace characters (space, tab, newline, return, formfeed). If the second argument `sep` is present and not `None`, it specifies a string to be used as the word separator. The returned list will then have one more item than the number of non-overlapping occurrences of the separator in the string. If

*maxsplit* is given, at most *maxsplit* number of splits occur, and the remainder of the string is returned as the final element of the list (thus, the list will have at most *maxsplit*+1 elements). If *maxsplit* is not specified or -1, then there is no limit on the number of splits (all possible splits are made).

The behavior of `split` on an empty string depends on the value of *sep*. If *sep* is not specified, or specified as `None`, the result will be an empty list. If *sep* is specified as any string, the result will be a list containing one element which is an empty string.

`string.rsplit` (*s* [, *sep* [, *maxsplit* ] ])

Return a list of the words of the string *s*, scanning *s* from the end. To all intents and purposes, the resulting list of words is the same as returned by `split` (), except when the optional third argument *maxsplit* is explicitly specified and nonzero. If *maxsplit* is given, at most *maxsplit* number of splits – the *rightmost* ones – occur, and the remainder of the string is returned as the first element of the list (thus, the list will have at most *maxsplit*+1 elements). New in version 2.4.

`string.splitfields` (*s* [, *sep* [, *maxsplit* ] ])

This function behaves identically to `split` (). (In the past, `split` () was only used with one argument, while `splitfields` () was only used with two arguments.)

`string.join` (*words* [, *sep* ])

Concatenate a list or tuple of words with intervening occurrences of *sep*. The default value for *sep* is a single space character. It is always true that `string.join(string.split(s, sep), sep)` equals *s*.

`string.joinfields` (*words* [, *sep* ])

This function behaves identically to `join` (). (In the past, `join` () was only used with one argument, while `joinfields` () was only used with two arguments.) Note that there is no `joinfields` () method on string objects; use the `join` () method instead.

`string.lstrip` (*s* [, *chars* ])

Return a copy of the string with leading characters removed. If *chars* is omitted or `None`, whitespace characters are removed. If given and not `None`, *chars* must be a string; the characters in the string will be stripped from the beginning of the string this method is called on. Changed in version 2.2.3: The *chars* parameter was added. The *chars* parameter cannot be passed in earlier 2.2 versions.

`string.rstrip` (*s* [, *chars* ])

Return a copy of the string with trailing characters removed. If *chars* is omitted or `None`, whitespace characters are removed. If given and not `None`, *chars* must be a string; the characters in the string will be stripped from the end of the string this method is called on. Changed in version 2.2.3: The *chars* parameter was added. The *chars* parameter cannot be passed in earlier 2.2 versions.

`string.strip` (*s* [, *chars* ])

Return a copy of the string with leading and trailing characters removed. If *chars* is omitted or `None`, whitespace characters are removed. If given and not `None`, *chars* must be a string; the characters in the string will be stripped from the both ends of the string this method is called on. Changed in version 2.2.3: The *chars* parameter was added. The *chars* parameter cannot be passed in earlier 2.2 versions.

`string.swapcase` (*s*)

Return a copy of *s*, but with lower case letters converted to upper case and vice versa.

`string.translate` (*s*, *table* [, *deletechars* ])

Delete all characters from *s* that are in *deletechars* (if present), and then translate the characters using *table*, which must be a 256-character string giving the translation for each character value, indexed by its ordinal. If *table* is `None`, then only the character deletion step is performed.

`string.upper` (*s*)

Return a copy of *s*, but with lower case letters converted to upper case.

`string.ljust` (*s*, *width* [, *fillchar* ])

`string.rjust` (*s*, *width* [, *fillchar* ])

`string.center` (*s*, *width* [, *fillchar* ])

These functions respectively left-justify, right-justify and center a string in a field of given width. They return a string that is at least *width* characters wide, created by padding the string *s* with the character *fillchar* (default is a space) until the given width on the right, left or both sides. The string is never truncated.

`string.zfill` (*s*, *width*)

Pad a numeric string on the left with zero digits until the given width is reached. Strings starting with a sign are handled correctly.

`string.replace` (*str*, *old*, *new* [, *maxreplace* ])

Return a copy of string *str* with all occurrences of substring *old* replaced by *new*. If the optional argument *maxreplace* is given, the first *maxreplace* occurrences are replaced.

## 7.2 re — Regular expression operations

This module provides regular expression matching operations similar to those found in Perl. Both patterns and strings to be searched can be Unicode strings as well as 8-bit strings.

Regular expressions use the backslash character (`'\'`) to indicate special forms or to allow special characters to be used without invoking their special meaning. This collides with Python's usage of the same character for the same purpose in string literals; for example, to match a literal backslash, one might have to write `'\\'` as the pattern string, because the regular expression must be `\\`, and each backslash must be expressed as `\\` inside a regular Python string literal.

The solution is to use Python's raw string notation for regular expression patterns; backslashes are not handled in any special way in a string literal prefixed with `'r'`. So `r"\n"` is a two-character string containing `'\'` and `'n'`, while `"\n"` is a one-character string containing a newline. Usually patterns will be expressed in Python code using this raw string notation.

It is important to note that most regular expression operations are available as module-level functions and `RegexObject` methods. The functions are shortcuts that don't require you to compile a regex object first, but miss some fine-tuning parameters.

### See Also:

**Mastering Regular Expressions** Book on regular expressions by Jeffrey Friedl, published by O'Reilly. The second edition of the book no longer covers Python at all, but the first edition covered writing good regular expression patterns in great detail.

### 7.2.1 Regular Expression Syntax

A regular expression (or RE) specifies a set of strings that matches it; the functions in this module let you check if a particular string matches a given regular expression (or if a given regular expression matches a particular string, which comes down to the same thing).

Regular expressions can be concatenated to form new regular expressions; if *A* and *B* are both regular expressions, then *AB* is also a regular expression. In general, if a string *p* matches *A* and another string *q* matches *B*, the string *pq* will match *AB*. This holds unless *A* or *B* contain low precedence operations; boundary conditions between *A* and *B*; or have numbered group references. Thus, complex expressions can easily be constructed from simpler primitive expressions like the ones described here. For details of the theory and implementation of regular expressions, consult the Friedl book referenced above, or almost any textbook about compiler construction.

A brief explanation of the format of regular expressions follows. For further information and a gentler presentation, consult the *regex-howto*.

Regular expressions can contain both special and ordinary characters. Most ordinary characters, like 'A', 'a', or '0', are the simplest regular expressions; they simply match themselves. You can concatenate ordinary characters, so last matches the string 'last'. (In the rest of this section, we'll write RE's in this special style, usually without quotes, and strings to be matched 'in single quotes'.)

Some characters, like '|' or '(', are special. Special characters either stand for classes of ordinary characters, or affect how the regular expressions around them are interpreted. Regular expression pattern strings may not contain null bytes, but can specify the null byte using the `\number` notation, e.g., `'\x00'`.

The special characters are:

- '.' (Dot.) In the default mode, this matches any character except a newline. If the `DOTALL` flag has been specified, this matches any character including a newline.
- '^' (Caret.) Matches the start of the string, and in `MULTILINE` mode also matches immediately after each newline.
- '\$' Matches the end of the string or just before the newline at the end of the string, and in `MULTILINE` mode also matches before a newline. `foo` matches both 'foo' and 'foobar', while the regular expression `foo$` matches only 'foo'. More interestingly, searching for `foo.$` in `'foo1\nfoo2\n'` matches 'foo2' normally, but 'foo1' in `MULTILINE` mode; searching for a single `$` in `'foo\n'` will find two (empty) matches: one just before the newline, and one at the end of the string.
- '\*' Causes the resulting RE to match 0 or more repetitions of the preceding RE, as many repetitions as are possible. `ab*` will match 'a', 'ab', or 'a' followed by any number of 'b's.
- '+' Causes the resulting RE to match 1 or more repetitions of the preceding RE. `ab+` will match 'a' followed by any non-zero number of 'b's; it will not match just 'a'.
- '?' Causes the resulting RE to match 0 or 1 repetitions of the preceding RE. `ab?` will match either 'a' or 'ab'.
- \*?, +?, ??** The '\*', '+', and '?' qualifiers are all *greedy*; they match as much text as possible. Sometimes this behaviour isn't desired; if the RE `<.*>` is matched against `'<H1>title</H1>'`, it will match the entire string, and not just `'<H1>'`. Adding '?' after the qualifier makes it perform the match in *non-greedy* or *minimal* fashion; as few characters as possible will be matched. Using `.*?` in the previous expression will match only `'<H1>'`.
- {m}** Specifies that exactly *m* copies of the previous RE should be matched; fewer matches cause the entire RE not to match. For example, `a{6}` will match exactly six 'a' characters, but not five.
- {m, n}** Causes the resulting RE to match from *m* to *n* repetitions of the preceding RE, attempting to match as many repetitions as possible. For example, `a{3, 5}` will match from 3 to 5 'a' characters. Omitting *m* specifies a lower bound of zero, and omitting *n* specifies an infinite upper bound. As an example, `a{4, }b` will match `aaaab` or a thousand 'a' characters followed by a b, but not `aaab`. The comma may not be omitted or the modifier would be confused with the previously described form.
- {m, n}?** Causes the resulting RE to match from *m* to *n* repetitions of the preceding RE, attempting to match as few repetitions as possible. This is the non-greedy version of the previous qualifier. For example, on the 6-character string `'aaaaaa'`, `a{3, 5}` will match 5 'a' characters, while `a{3, 5}?` will only match 3 characters.
- '\' Either escapes special characters (permitting you to match characters like '\*', '?', and so forth), or signals a special sequence; special sequences are discussed below.

If you're not using a raw string to express the pattern, remember that Python also uses the backslash as an escape sequence in string literals; if the escape sequence isn't recognized by Python's parser, the backslash and subsequent character are included in the resulting string. However, if Python would recognize the resulting sequence, the backslash should be repeated twice. This is complicated and hard to understand, so it's highly recommended that you use raw strings for all but the simplest expressions.

[ ] Used to indicate a set of characters. In a set:

- Characters can be listed individually, e.g. `[amk]` will match 'a', 'm', or 'k'.

- Ranges of characters can be indicated by giving two characters and separating them by a `'-'`, for example `[a-z]` will match any lowercase ASCII letter, `[0-5][0-9]` will match all the two-digits numbers from 00 to 59, and `[0-9A-Fa-f]` will match any hexadecimal digit. If `-` is escaped (e.g. `[a\ -z]`) or if it's placed as the first or last character (e.g. `[a-]`), it will match a literal `'-'`.
- Special characters lose their special meaning inside sets. For example, `[(+*)]` will match any of the literal characters `'('`, `'+'`, `'*'`, or `)'`.
- Character classes such as `\w` or `\S` (defined below) are also accepted inside a set, although the characters they match depends on whether `LOCALE` or `UNICODE` mode is in force.
- Characters that are not within a range can be matched by *complementing* the set. If the first character of the set is `'^'`, all the characters that are *not* in the set will be matched. For example, `[^5]` will match any character except `'5'`, and `[^]` will match any character except `'^'`. `^` has no special meaning if it's not the first character in the set.
- To match a literal `']'` inside a set, precede it with a backslash, or place it at the beginning of the set. For example, both `[(\ [ \ ] { } ]` and `[ ] ( ) [ { } ]` will both match a parenthesis.

`'|'` `A|B`, where `A` and `B` can be arbitrary REs, creates a regular expression that will match either `A` or `B`. An arbitrary number of REs can be separated by the `'|'` in this way. This can be used inside groups (see below) as well. As the target string is scanned, REs separated by `'|'` are tried from left to right. When one pattern completely matches, that branch is accepted. This means that once `A` matches, `B` will not be tested further, even if it would produce a longer overall match. In other words, the `'|'` operator is never greedy. To match a literal `'|'`, use `\|`, or enclose it inside a character class, as in `[|]`.

- `(...)` Matches whatever regular expression is inside the parentheses, and indicates the start and end of a group; the contents of a group can be retrieved after a match has been performed, and can be matched later in the string with the `\number` special sequence, described below. To match the literals `'('` or `)'`, use `\(` or `\)`, or enclose them inside a character class: `[ ( ) ]`.
- `(?...)` This is an extension notation (a `'?'` following a `'('` is not meaningful otherwise). The first character after the `'?'` determines what the meaning and further syntax of the construct is. Extensions usually do not create a new group; `(?P<name>...)` is the only exception to this rule. Following are the currently supported extensions.

**(?iLmsux)** (One or more letters from the set `'i'`, `'L'`, `'m'`, `'s'`, `'u'`, `'x'`.) The group matches the empty string; the letters set the corresponding flags: `re.I` (ignore case), `re.L` (locale dependent), `re.M` (multi-line), `re.S` (dot matches all), `re.U` (Unicode dependent), and `re.X` (verbose), for the entire regular expression. (The flags are described in *Module Contents*.) This is useful if you wish to include the flags as part of the regular expression, instead of passing a *flag* argument to the `re.compile()` function.

Note that the `(?x)` flag changes how the expression is parsed. It should be used first in the expression string, or after one or more whitespace characters. If there are non-whitespace characters before the flag, the results are undefined.

- `(?:...)` A non-capturing version of regular parentheses. Matches whatever regular expression is inside the parentheses, but the substring matched by the group *cannot* be retrieved after performing a match or referenced later in the pattern.
- `(?P<name>...)` Similar to regular parentheses, but the substring matched by the group is accessible within the rest of the regular expression via the symbolic group name *name*. Group names must be valid Python identifiers, and each group name must be defined only once within a regular expression. A symbolic group is also a numbered group, just as if the group were not named. So the group named `id` in the example below can also be referenced as the numbered group 1.

For example, if the pattern is `(?P<id>[a-zA-Z_]\w*)`, the group can be referenced by its name in arguments to methods of match objects, such as `m.group('id')` or `m.end('id')`, and also by name in the regular expression itself (using `(?P=id)`) and replacement text given to `.sub()` (using `\g<id>`).

(?P=name) Matches whatever text was matched by the earlier group named *name*.

(?#. . .) A comment; the contents of the parentheses are simply ignored.

(?= . . .) Matches if . . . matches next, but doesn't consume any of the string. This is called a lookahead assertion. For example, `Isaac (?=Asimov)` will match `'Isaac '` only if it's followed by `'Asimov'`.

(?! . . .) Matches if . . . doesn't match next. This is a negative lookahead assertion. For example, `Isaac (?!Asimov)` will match `'Isaac '` only if it's *not* followed by `'Asimov'`.

(?<= . . .) Matches if the current position in the string is preceded by a match for . . . that ends at the current position. This is called a *positive lookbehind assertion*. `(?<=abc)def` will find a match in `abcdef`, since the lookbehind will back up 3 characters and check if the contained pattern matches. The contained pattern must only match strings of some fixed length, meaning that `abc` or `a|b` are allowed, but `a*` and `a{3,4}` are not. Note that patterns which start with positive lookbehind assertions will not match at the beginning of the string being searched; you will most likely want to use the `search()` function rather than the `match()` function:

```
>>> import re
>>> m = re.search('( ?<=abc)def', 'abcdef')
>>> m.group(0)
'def'
```

This example looks for a word following a hyphen:

```
>>> m = re.search('( ?<=-)\w+', 'spam-egg')
>>> m.group(0)
'egg'
```

(?<! . . .) Matches if the current position in the string is not preceded by a match for . . . This is called a *negative lookbehind assertion*. Similar to positive lookbehind assertions, the contained pattern must only match strings of some fixed length. Patterns which start with negative lookbehind assertions may match at the beginning of the string being searched.

(?(id/name)yes-pattern|no-pattern) Will try to match with *yes-pattern* if the group with given *id* or *name* exists, and with *no-pattern* if it doesn't. *no-pattern* is optional and can be omitted. For example, `(<)?(\w+@\w+(?:\.\w+)+)(?(1)>)` is a poor email matching pattern, which will match with `'<user@host.com>'` as well as `'user@host.com'`, but not with `'<user@host.com'`. New in version 2.4.

The special sequences consist of `'\'` and a character from the list below. If the ordinary character is not on the list, then the resulting RE will match the second character. For example, `\$` matches the character `'$'`.

**\number** Matches the contents of the group of the same number. Groups are numbered starting from 1. For example, `(.+)\1` matches `'the the'` or `'55 55'`, but not `'the end'` (note the space after the group). This special sequence can only be used to match one of the first 99 groups. If the first digit of *number* is 0, or *number* is 3 octal digits long, it will not be interpreted as a group match, but as the character with octal value *number*. Inside the `'['` and `']'` of a character class, all numeric escapes are treated as characters.

**\A** Matches only at the start of the string.

**\b** Matches the empty string, but only at the beginning or end of a word. A word is defined as a sequence of alphanumeric or underscore characters, so the end of a word is indicated by whitespace or a non-alphanumeric, non-underscore character. Note that formally, `\b` is defined as the boundary between a `\w` and a `\W` character (or vice versa), or between `\w` and the beginning/end of the string, so the precise set of characters deemed to be alphanumeric depends on the values of the `UNICODE` and `LOCALE` flags. For example, `r'\bfoo\b'` matches `'foo'`, `'foo.'`, `'(foo)'`, `'bar foo baz'` but not `'foobar'` or `'foo3'`. Inside a character range, `\b` represents the backspace character, for compatibility with Python's string literals.

**\B** Matches the empty string, but only when it is *not* at the beginning or end of a word. This means that `r'py\b'` matches `'python'`, `'py3'`, `'py2'`, but not `'py'`, `'py.'`, or `'py!'`. `\B` is just the opposite of `\b`, so is also subject to the settings of `LOCALE` and `UNICODE`.

- `\d` When the `UNICODE` flag is not specified, matches any decimal digit; this is equivalent to the set `[0-9]`. With `UNICODE`, it will match whatever is classified as a decimal digit in the Unicode character properties database.
- `\D` When the `UNICODE` flag is not specified, matches any non-digit character; this is equivalent to the set `[^0-9]`. With `UNICODE`, it will match anything other than character marked as digits in the Unicode character properties database.
- `\s` When the `UNICODE` flag is not specified, it matches any whitespace character, this is equivalent to the set `[\t\n\r\f\v]`. The `LOCALE` flag has no extra effect on matching of the space. If `UNICODE` is set, this will match the characters `[\t\n\r\f\v]` plus whatever is classified as space in the Unicode character properties database.
- `\S` When the `UNICODE` flags is not specified, matches any non-whitespace character; this is equivalent to the set `[^\t\n\r\f\v]` The `LOCALE` flag has no extra effect on non-whitespace match. If `UNICODE` is set, then any character not marked as space in the Unicode character properties database is matched.
- `\w` When the `LOCALE` and `UNICODE` flags are not specified, matches any alphanumeric character and the underscore; this is equivalent to the set `[a-zA-Z0-9_]`. With `LOCALE`, it will match the set `[0-9_]` plus whatever characters are defined as alphanumeric for the current locale. If `UNICODE` is set, this will match the characters `[0-9_]` plus whatever is classified as alphanumeric in the Unicode character properties database.
- `\W` When the `LOCALE` and `UNICODE` flags are not specified, matches any non-alphanumeric character; this is equivalent to the set `[^a-zA-Z0-9_]`. With `LOCALE`, it will match any character not in the set `[0-9_]`, and not defined as alphanumeric for the current locale. If `UNICODE` is set, this will match anything other than `[0-9_]` plus characters classed as not alphanumeric in the Unicode character properties database.
- `\Z` Matches only at the end of the string.

If both `LOCALE` and `UNICODE` flags are included for a particular sequence, then `LOCALE` flag takes effect first followed by the `UNICODE`.

Most of the standard escapes supported by Python string literals are also accepted by the regular expression parser:

```
\a      \b      \f      \n
\r      \t      \v      \x
\\
```

(Note that `\b` is used to represent word boundaries, and means “backspace” only inside character classes.)

Octal escapes are included in a limited form: If the first digit is a 0, or if there are three octal digits, it is considered an octal escape. Otherwise, it is a group reference. As for string literals, octal escapes are always at most three digits in length.

## 7.2.2 Module Contents

The module defines several functions, constants, and an exception. Some of the functions are simplified versions of the full featured methods for compiled regular expressions. Most non-trivial applications always use the compiled form.

`re.compile` (*pattern*, *flags=0*)

Compile a regular expression pattern into a regular expression object, which can be used for matching using its `match()` and `search()` methods, described below.

The expression’s behaviour can be modified by specifying a *flags* value. Values can be any of the following variables, combined using bitwise OR (the `|` operator).

The sequence

```
prog = re.compile(pattern)
result = prog.match(string)
```

is equivalent to

```
result = re.match(pattern, string)
```

but using `re.compile()` and saving the resulting regular expression object for reuse is more efficient when the expression will be used several times in a single program.

---

**Note:** The compiled versions of the most recent patterns passed to `re.match()`, `re.search()` or `re.compile()` are cached, so programs that use only a few regular expressions at a time needn't worry about compiling regular expressions.

---

**re.DEBUG**

Display debug information about compiled expression.

**re.I**

**re.IGNORECASE**

Perform case-insensitive matching; expressions like `[A-Z]` will match lowercase letters, too. This is not affected by the current locale.

**re.L**

**re.LOCALE**

Make `\w`, `\W`, `\b`, `\B`, `\s` and `\S` dependent on the current locale.

**re.M**

**re.MULTILINE**

When specified, the pattern character `^` matches at the beginning of the string and at the beginning of each line (immediately following each newline); and the pattern character `$` matches at the end of the string and at the end of each line (immediately preceding each newline). By default, `^` matches only at the beginning of the string, and `$` only at the end of the string and immediately before the newline (if any) at the end of the string.

**re.S**

**re.DOTALL**

Make the `.` special character match any character at all, including a newline; without this flag, `.` will match anything *except* a newline.

**re.U**

**re.UNICODE**

Make `\w`, `\W`, `\b`, `\B`, `\d`, `\D`, `\s` and `\S` dependent on the Unicode character properties database. New in version 2.0.

**re.X**

**re.VERBOSE**

This flag allows you to write regular expressions that look nicer. Whitespace within the pattern is ignored, except when in a character class or preceded by an unescaped backslash, and, when a line contains a `#` neither in a character class or preceded by an unescaped backslash, all characters from the leftmost such `#` through the end of the line are ignored.

That means that the two following regular expression objects that match a decimal number are functionally equal:

```
a = re.compile(r"""\d + # the integral part
               \.  # the decimal point
               \d * # some fractional digits""", re.X)
b = re.compile(r"\d+\.\d*")
```

`re.search` (*pattern*, *string*, *flags=0*)

Scan through *string* looking for a location where the regular expression *pattern* produces a match, and return a corresponding `MatchObject` instance. Return `None` if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

`re.match` (*pattern*, *string*, *flags=0*)

If zero or more characters at the beginning of *string* match the regular expression *pattern*, return a corresponding `MatchObject` instance. Return `None` if the string does not match the pattern; note that this is different from a zero-length match.

Note that even in `MULTILINE` mode, `re.match()` will only match at the beginning of the string and not at the beginning of each line.

If you want to locate a match anywhere in *string*, use `search()` instead (see also *search() vs. match()*).

`re.split` (*pattern*, *string*, *maxsplit=0*, *flags=0*)

Split *string* by the occurrences of *pattern*. If capturing parentheses are used in *pattern*, then the text of all groups in the pattern are also returned as part of the resulting list. If *maxsplit* is nonzero, at most *maxsplit* splits occur, and the remainder of the string is returned as the final element of the list. (Incompatibility note: in the original Python 1.5 release, *maxsplit* was ignored. This has been fixed in later releases.)

```
>>> re.split('\W+', 'Words, words, words.')
['Words', 'words', 'words', '']
>>> re.split('(\W+)', 'Words, words, words.')
['Words', '', ' ', 'words', '', ' ', 'words', '.', '']
>>> re.split('\W+', 'Words, words, words.', 1)
['Words', 'words, words.']
>>> re.split('[a-f]+', '0a3B9', flags=re.IGNORECASE)
['0', '3', '9']
```

If there are capturing groups in the separator and it matches at the start of the string, the result will start with an empty string. The same holds for the end of the string:

```
>>> re.split('(\W+)', '...words, words...')
['', '...', 'words', '', ' ', 'words', '...', '']
```

That way, separator components are always found at the same relative indices within the result list (e.g., if there's one capturing group in the separator, the 0th, the 2nd and so forth).

Note that *split* will never split a string on an empty pattern match. For example:

```
>>> re.split('x*', 'foo')
['foo']
>>> re.split("(?m)^\$", "foo\n\nbar\n")
['foo\n\nbar\n']
```

Changed in version 2.7: Added the optional flags argument.

`re.findall` (*pattern*, *string*, *flags=0*)

Return all non-overlapping matches of *pattern* in *string*, as a list of strings. The *string* is scanned left-to-right, and matches are returned in the order found. If one or more groups are present in the pattern, return a list of groups; this will be a list of tuples if the pattern has more than one group. Empty matches are included in the result unless they touch the beginning of another match. New in version 1.5.2. Changed in version 2.4: Added the optional flags argument.

`re.finditer` (*pattern*, *string*, *flags=0*)

Return an *iterator* yielding `MatchObject` instances over all non-overlapping matches for the RE *pattern* in

*string*. The *string* is scanned left-to-right, and matches are returned in the order found. Empty matches are included in the result unless they touch the beginning of another match. New in version 2.2. Changed in version 2.4: Added the optional flags argument.

`re.sub(pattern, repl, string, count=0, flags=0)`

Return the string obtained by replacing the leftmost non-overlapping occurrences of *pattern* in *string* by the replacement *repl*. If the pattern isn't found, *string* is returned unchanged. *repl* can be a string or a function; if it is a string, any backslash escapes in it are processed. That is, `\n` is converted to a single newline character, `\r` is converted to a carriage return, and so forth. Unknown escapes such as `\j` are left alone. Backreferences, such as `\6`, are replaced with the substring matched by group 6 in the pattern. For example:

```
>>> re.sub(r'def\s+([a-zA-Z_][a-zA-Z_0-9]*)\s*(\s*\):',
...        r'static PyObject*\numpy_\1(void)\n{',
...        'def myfunc():')
'static PyObject*\numpy_myfunc(void)\n{'
```

If *repl* is a function, it is called for every non-overlapping occurrence of *pattern*. The function takes a single match object argument, and returns the replacement string. For example:

```
>>> def dashrepl(matchobj):
...     if matchobj.group(0) == '-': return ' '
...     else: return '-'
>>> re.sub('-{1,2}', dashrepl, 'pro---gram-files')
'pro--gram files'
>>> re.sub(r'\sAND\s', ' & ', 'Baked Beans And Spam', flags=re.IGNORECASE)
'Baked Beans & Spam'
```

The pattern may be a string or an RE object.

The optional argument *count* is the maximum number of pattern occurrences to be replaced; *count* must be a non-negative integer. If omitted or zero, all occurrences will be replaced. Empty matches for the pattern are replaced only when not adjacent to a previous match, so `sub('x*', '-', 'abc')` returns `'-a-b-c-'`.

In addition to character escapes and backreferences as described above, `\g<name>` will use the substring matched by the group named *name*, as defined by the `(?P<name>...)` syntax. `\g<number>` uses the corresponding group number; `\g<2>` is therefore equivalent to `\2`, but isn't ambiguous in a replacement such as `\g<2>0`. `\20` would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character `'0'`. The backreference `\g<0>` substitutes in the entire substring matched by the RE. Changed in version 2.7: Added the optional flags argument.

`re.subn(pattern, repl, string, count=0, flags=0)`

Perform the same operation as `sub()`, but return a tuple (*new\_string*, *number\_of\_subs\_made*). Changed in version 2.7: Added the optional flags argument.

`re.escape(string)`

Return *string* with all non-alphanumerics backslashed; this is useful if you want to match an arbitrary literal string that may have regular expression metacharacters in it.

`re.purge()`

Clear the regular expression cache.

**exception** `re.error`

Exception raised when a string passed to one of the functions here is not a valid regular expression (for example, it might contain unmatched parentheses) or when some other error occurs during compilation or matching. It is never an error if a string contains no match for a pattern.

## 7.2.3 Regular Expression Objects

### class `re.RegexObject`

The `RegexObject` class supports the following methods and attributes:

#### `search (string[, pos[, endpos ]])`

Scan through *string* looking for a location where this regular expression produces a match, and return a corresponding `MatchObject` instance. Return `None` if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

The optional second parameter *pos* gives an index in the string where the search is to start; it defaults to 0. This is not completely equivalent to slicing the string; the `'^'` pattern character matches at the real beginning of the string and at positions just after a newline, but not necessarily at the index where the search is to start.

The optional parameter *endpos* limits how far the string will be searched; it will be as if the string is *endpos* characters long, so only the characters from *pos* to *endpos* - 1 will be searched for a match. If *endpos* is less than *pos*, no match will be found, otherwise, if *rx* is a compiled regular expression object, `rx.search(string, 0, 50)` is equivalent to `rx.search(string[:50], 0)`.

```
>>> pattern = re.compile("d")
>>> pattern.search("dog")          # Match at index 0
<_sre.SRE_Match object at ...>
>>> pattern.search("dog", 1)      # No match; search doesn't include the "d"
```

#### `match (string[, pos[, endpos ]])`

If zero or more characters at the *beginning* of *string* match this regular expression, return a corresponding `MatchObject` instance. Return `None` if the string does not match the pattern; note that this is different from a zero-length match.

The optional *pos* and *endpos* parameters have the same meaning as for the `search()` method.

```
>>> pattern = re.compile("o")
>>> pattern.match("dog")          # No match as "o" is not at the start of "dog".
>>> pattern.match("dog", 1)      # Match as "o" is the 2nd character of "dog".
<_sre.SRE_Match object at ...>
```

If you want to locate a match anywhere in *string*, use `search()` instead (see also *search() vs. match()*).

#### `split (string, maxsplit=0)`

Identical to the `split()` function, using the compiled pattern.

#### `findall (string[, pos[, endpos ]])`

Similar to the `findall()` function, using the compiled pattern, but also accepts optional *pos* and *endpos* parameters that limit the search region like for `match()`.

#### `finditer (string[, pos[, endpos ]])`

Similar to the `finditer()` function, using the compiled pattern, but also accepts optional *pos* and *endpos* parameters that limit the search region like for `match()`.

#### `sub (repl, string, count=0)`

Identical to the `sub()` function, using the compiled pattern.

#### `subn (repl, string, count=0)`

Identical to the `subn()` function, using the compiled pattern.

#### `flags`

The regex matching flags. This is a combination of the flags given to `compile()` and any `(?..)` inline flags in the pattern.

**groups**

The number of capturing groups in the pattern.

**groupindex**

A dictionary mapping any symbolic group names defined by `(?P<id>)` to group numbers. The dictionary is empty if no symbolic groups were used in the pattern.

**pattern**

The pattern string from which the RE object was compiled.

## 7.2.4 Match Objects

**class** `re.MatchObject`

Match Objects always have a boolean value of `True`, so that you can test whether e.g. `match()` resulted in a match with a simple if statement. They support the following methods and attributes:

**expand** (*template*)

Return the string obtained by doing backslash substitution on the template string *template*, as done by the `sub()` method. Escapes such as `\n` are converted to the appropriate characters, and numeric backreferences (`\1`, `\2`) and named backreferences (`\g<1>`, `\g<name>`) are replaced by the contents of the corresponding group.

**group** (`[group1, ... ]`)

Returns one or more subgroups of the match. If there is a single argument, the result is a single string; if there are multiple arguments, the result is a tuple with one item per argument. Without arguments, *group1* defaults to zero (the whole match is returned). If a *groupN* argument is zero, the corresponding return value is the entire matching string; if it is in the inclusive range `[1..99]`, it is the string matching the corresponding parenthesized group. If a group number is negative or larger than the number of groups defined in the pattern, an `IndexError` exception is raised. If a group is contained in a part of the pattern that did not match, the corresponding result is `None`. If a group is contained in a part of the pattern that matched multiple times, the last match is returned.

```
>>> m = re.match(r"(\w+) (\w+)", "Isaac Newton, physicist")
>>> m.group(0)           # The entire match
'Isaac Newton'
>>> m.group(1)           # The first parenthesized subgroup.
'Isaac'
>>> m.group(2)           # The second parenthesized subgroup.
'Newton'
>>> m.group(1, 2)       # Multiple arguments give us a tuple.
('Isaac', 'Newton')
```

If the regular expression uses the `(?P<name>...)` syntax, the *groupN* arguments may also be strings identifying groups by their group name. If a string argument is not used as a group name in the pattern, an `IndexError` exception is raised.

A moderately complicated example:

```
>>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Malcolm Reynolds")
>>> m.group('first_name')
'Malcolm'
>>> m.group('last_name')
'Reynolds'
```

Named groups can also be referred to by their index:

```
>>> m.group(1)
'Malcolm'
>>> m.group(2)
'Reynolds'
```

If a group matches multiple times, only the last match is accessible:

```
>>> m = re.match(r"(..)+", "alb2c3") # Matches 3 times.
>>> m.group(1) # Returns only the last match.
'c3'
```

### **groups** ([*default*])

Return a tuple containing all the subgroups of the match, from 1 up to however many groups are in the pattern. The *default* argument is used for groups that did not participate in the match; it defaults to `None`. (Incompatibility note: in the original Python 1.5 release, if the tuple was one element long, a string would be returned instead. In later versions (from 1.5.1 on), a singleton tuple is returned in such cases.)

For example:

```
>>> m = re.match(r"(\d+)\.(\d+)", "24.1632")
>>> m.groups()
('24', '1632')
```

If we make the decimal place and everything after it optional, not all groups might participate in the match. These groups will default to `None` unless the *default* argument is given:

```
>>> m = re.match(r"(\d+)\.?(d+)?", "24")
>>> m.groups() # Second group defaults to None.
('24', None)
>>> m.groups('0') # Now, the second group defaults to '0'.
('24', '0')
```

### **groupdict** ([*default*])

Return a dictionary containing all the *named* subgroups of the match, keyed by the subgroup name. The *default* argument is used for groups that did not participate in the match; it defaults to `None`. For example:

```
>>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Malcolm Reynolds")
>>> m.groupdict()
{'first_name': 'Malcolm', 'last_name': 'Reynolds'}
```

### **start** ([*group*])

### **end** ([*group*])

Return the indices of the start and end of the substring matched by *group*; *group* defaults to zero (meaning the whole matched substring). Return `-1` if *group* exists but did not contribute to the match. For a match object *m*, and a group *g* that did contribute to the match, the substring matched by group *g* (equivalent to `m.group(g)`) is

```
m.string[m.start(g):m.end(g)]
```

Note that `m.start(group)` will equal `m.end(group)` if *group* matched a null string. For example, after `m = re.search('b(c?)', 'cba')`, `m.start(0)` is 1, `m.end(0)` is 2, `m.start(1)` and `m.end(1)` are both 2, and `m.start(2)` raises an `IndexError` exception.

An example that will remove *remove\_this* from email addresses:

```
>>> email = "tony@tiremove_thisger.net"
>>> m = re.search("remove_this", email)
>>> email[:m.start()] + email[m.end():]
'tony@tiger.net'
```

**span** (*[group]*)

For `MatchObject` *m*, return the 2-tuple `(m.start(group), m.end(group))`. Note that if *group* did not contribute to the match, this is `(-1, -1)`. *group* defaults to zero, the entire match.

**pos**

The value of *pos* which was passed to the `search()` or `match()` method of the `RegexObject`. This is the index into the string at which the RE engine started looking for a match.

**endpos**

The value of *endpos* which was passed to the `search()` or `match()` method of the `RegexObject`. This is the index into the string beyond which the RE engine will not go.

**lastindex**

The integer index of the last matched capturing group, or `None` if no group was matched at all. For example, the expressions `(a)b`, `((a)(b))`, and `((ab))` will have `lastindex == 1` if applied to the string `'ab'`, while the expression `(a)(b)` will have `lastindex == 2`, if applied to the same string.

**lastgroup**

The name of the last matched capturing group, or `None` if the group didn't have a name, or if no group was matched at all.

**re**

The regular expression object whose `match()` or `search()` method produced this `MatchObject` instance.

**string**

The string passed to `match()` or `search()`.

## 7.2.5 Examples

### Checking For a Pair

In this example, we'll use the following helper function to display match objects a little more gracefully:

```
def displaymatch(match):
    if match is None:
        return None
    return '<Match: %r, groups=%r>' % (match.group(), match.groups())
```

Suppose you are writing a poker program where a player's hand is represented as a 5-character string with each character representing a card, "a" for ace, "k" for king, "q" for queen, "j" for jack, "t" for 10, and "2" through "9" representing the card with that value.

To see if a given string is a valid hand, one could do the following:

```
>>> valid = re.compile(r"^[a2-9tjqk]{5}$")
>>> displaymatch(valid.match("akt5q")) # Valid.
"<Match: 'akt5q', groups=()>"
>>> displaymatch(valid.match("akt5e")) # Invalid.
>>> displaymatch(valid.match("akt")) # Invalid.
>>> displaymatch(valid.match("727ak")) # Valid.
"<Match: '727ak', groups=()>"
```

That last hand, "727ak", contained a pair, or two of the same valued cards. To match this with a regular expression, one could use backreferences as such:

```
>>> pair = re.compile(r"*(.*)*\1")
>>> displaymatch(pair.match("717ak"))      # Pair of 7s.
"<Match: '717', groups=('7',)>"
>>> displaymatch(pair.match("718ak"))      # No pairs.
"<Match: '718', groups=('7',)>"
>>> displaymatch(pair.match("354aa"))      # Pair of aces.
"<Match: '354aa', groups=('a',)>"
```

To find out what card the pair consists of, one could use the `group()` method of `MatchObject` in the following manner:

```
>>> pair.match("717ak").group(1)
'7'

# Error because re.match() returns None, which doesn't have a group() method:
>>> pair.match("718ak").group(1)
Traceback (most recent call last):
  File "<pyshell#23>", line 1, in <module>
    re.match(r"*(.*)*\1", "718ak").group(1)
AttributeError: 'NoneType' object has no attribute 'group'

>>> pair.match("354aa").group(1)
'a'
```

## Simulating `scanf()`

Python does not currently have an equivalent to `scanf()`. Regular expressions are generally more powerful, though also more verbose, than `scanf()` format strings. The table below offers some more-or-less equivalent mappings between `scanf()` format tokens and regular expressions.

<code>scanf()</code> Token	Regular Expression
<code>%c</code>	<code>.</code>
<code>%5c</code>	<code>.{5}</code>
<code>%d</code>	<code>[+]? \d+</code>
<code>%e, %E, %f, %g</code>	<code>[+]? (\d+ (\.\d*)?   \.\d+) ([eE] [+]? \d+)?</code>
<code>%i</code>	<code>[+]? (0[xX] [\dA-Fa-f]+   0[0-7]*   \d+)</code>
<code>%o</code>	<code>[+]? [0-7]+</code>
<code>%s</code>	<code>\S+</code>
<code>%u</code>	<code>\d+</code>
<code>%x, %X</code>	<code>[+]? (0[xX])? [\dA-Fa-f]+</code>

To extract the filename and numbers from a string like

```
/usr/sbin/sendmail - 0 errors, 4 warnings
```

you would use a `scanf()` format like

```
%s - %d errors, %d warnings
```

The equivalent regular expression would be

```
(\S+) - (\d+) errors, (\d+) warnings
```

### search() vs. match()

Python offers two different primitive operations based on regular expressions: `re.match()` checks for a match only at the beginning of the string, while `re.search()` checks for a match anywhere in the string (this is what Perl does by default).

For example:

```
>>> re.match("c", "abcdef") # No match
>>> re.search("c", "abcdef") # Match
<_sre.SRE_Match object at ...>
```

Regular expressions beginning with `'^'` can be used with `search()` to restrict the match at the beginning of the string:

```
>>> re.match("c", "abcdef") # No match
>>> re.search("^c", "abcdef") # No match
>>> re.search("^a", "abcdef") # Match
<_sre.SRE_Match object at ...>
```

Note however that in `MULTILINE` mode `match()` only matches at the beginning of the string, whereas using `search()` with a regular expression beginning with `'^'` will match at the beginning of each line.

```
>>> re.match('X', 'A\nB\nX', re.MULTILINE) # No match
>>> re.search('^X', 'A\nB\nX', re.MULTILINE) # Match
<_sre.SRE_Match object at ...>
```

### Making a Phonebook

`split()` splits a string into a list delimited by the passed pattern. The method is invaluable for converting textual data into data structures that can be easily read and modified by Python as demonstrated in the following example that creates a phonebook.

First, here is the input. Normally it may come from a file, here we are using triple-quoted string syntax:

```
>>> text = """Ross McFluff: 834.345.1254 155 Elm Street
...
... Ronald Heathmore: 892.345.3428 436 Finley Avenue
... Frank Burger: 925.541.7625 662 South Dogwood Way
...
... Heather Albrecht: 548.326.4584 919 Park Place"""
```

The entries are separated by one or more newlines. Now we convert the string into a list with each nonempty line having its own entry:

```
>>> entries = re.split("\n+", text)
>>> entries
['Ross McFluff: 834.345.1254 155 Elm Street',
 'Ronald Heathmore: 892.345.3428 436 Finley Avenue',
 'Frank Burger: 925.541.7625 662 South Dogwood Way',
 'Heather Albrecht: 548.326.4584 919 Park Place']
```

Finally, split each entry into a list with first name, last name, telephone number, and address. We use the `maxsplit` parameter of `split()` because the address has spaces, our splitting pattern, in it:

```
>>> [re.split(" :? ", entry, 3) for entry in entries]
[['Ross', 'McFluff', '834.345.1254', '155 Elm Street'],
 ['Ronald', 'Heathmore', '892.345.3428', '436 Finley Avenue'],
```

```
[ 'Frank', 'Burger', '925.541.7625', '662 South Dogwood Way' ],
[ 'Heather', 'Albrecht', '548.326.4584', '919 Park Place' ]]
```

The `:?` pattern matches the colon after the last name, so that it does not occur in the result list. With a `maxsplit` of 4, we could separate the house number from the street name:

```
>>> [re.split("?:?", entry, 4) for entry in entries]
[[ 'Ross', 'McFluff', '834.345.1254', '155', 'Elm Street' ],
[ 'Ronald', 'Heathmore', '892.345.3428', '436', 'Finley Avenue' ],
[ 'Frank', 'Burger', '925.541.7625', '662', 'South Dogwood Way' ],
[ 'Heather', 'Albrecht', '548.326.4584', '919', 'Park Place' ]]
```

## Text Munging

`sub()` replaces every occurrence of a pattern with a string or the result of a function. This example demonstrates using `sub()` with a function to “munge” text, or randomize the order of all the characters in each word of a sentence except for the first and last characters:

```
>>> def repl(m):
...     inner_word = list(m.group(2))
...     random.shuffle(inner_word)
...     return m.group(1) + "".join(inner_word) + m.group(3)
>>> text = "Professor Abdolmalek, please report your absences promptly."
>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Poefsrosr Aealmlbdk, pslaee reorpt your abnseces plmrptoy.'
>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Pofsroser Aodlambelk, plasee reorpt yuor asnebces potlmrpy.'
```

## Finding all Adverbs

`findall()` matches *all* occurrences of a pattern, not just the first one as `search()` does. For example, if one was a writer and wanted to find all of the adverbs in some text, he or she might use `findall()` in the following manner:

```
>>> text = "He was carefully disguised but captured quickly by police."
>>> re.findall(r"\w+ly", text)
['carefully', 'quickly']
```

## Finding all Adverbs and their Positions

If one wants more information about all matches of a pattern than the matched text, `finditer()` is useful as it provides instances of `MatchObject` instead of strings. Continuing with the previous example, if one was a writer who wanted to find all of the adverbs *and their positions* in some text, he or she would use `finditer()` in the following manner:

```
>>> text = "He was carefully disguised but captured quickly by police."
>>> for m in re.finditer(r"\w+ly", text):
...     print '%02d-%02d: %s' % (m.start(), m.end(), m.group(0))
07-16: carefully
40-47: quickly
```

## Raw String Notation

Raw string notation (`r"text"`) keeps regular expressions sane. Without it, every backslash (`'\'`) in a regular expression would have to be prefixed with another one to escape it. For example, the two following lines of code are

functionally identical:

```
>>> re.match(r"\W(.)\1\W", " ff ")
<_sre.SRE_Match object at ...>
>>> re.match("\W(.)\1\W", " ff ")
<_sre.SRE_Match object at ...>
```

When one wants to match a literal backslash, it must be escaped in the regular expression. With raw string notation, this means `r"\\"`. Without raw string notation, one must use `"\\\\"`, making the following lines of code functionally identical:

```
>>> re.match(r"\\", r"\")
<_sre.SRE_Match object at ...>
>>> re.match("\\\\", r"\")
<_sre.SRE_Match object at ...>
```

## 7.3 struct — Interpret strings as packed binary data

This module performs conversions between Python values and C structs represented as Python strings. This can be used in handling binary data stored in files or from network connections, among other sources. It uses *Format Strings* as compact descriptions of the layout of the C structs and the intended conversion to/from Python values.

---

**Note:** By default, the result of packing a given C struct includes pad bytes in order to maintain proper alignment for the C types involved; similarly, alignment is taken into account when unpacking. This behavior is chosen so that the bytes of a packed struct correspond exactly to the layout in memory of the corresponding C struct. To handle platform-independent data formats or omit implicit pad bytes, use *standard size and alignment* instead of *native size and alignment*: see *Byte Order, Size, and Alignment* for details.

---

### 7.3.1 Functions and Exceptions

The module defines the following exception and functions:

**exception** `struct.error`

Exception raised on various occasions; argument is a string describing what is wrong.

`struct.pack` (*fmt*, *v1*, *v2*, ...)

Return a string containing the values *v1*, *v2*, ... packed according to the given format. The arguments must match the values required by the format exactly.

`struct.pack_into` (*fmt*, *buffer*, *offset*, *v1*, *v2*, ...)

Pack the values *v1*, *v2*, ... according to the given format, write the packed bytes into the writable *buffer* starting at *offset*. Note that the offset is a required argument. New in version 2.5.

`struct.unpack` (*fmt*, *string*)

Unpack the string (presumably packed by `pack` (*fmt*, ...)) according to the given format. The result is a tuple even if it contains exactly one item. The string must contain exactly the amount of data required by the format (`len(string)` must equal `calcsize(fmt)`).

`struct.unpack_from` (*fmt*, *buffer*[, *offset*=0])

Unpack the *buffer* according to the given format. The result is a tuple even if it contains exactly one item. The *buffer* must contain at least the amount of data required by the format (`len(buffer[offset:])` must be at least `calcsize(fmt)`). New in version 2.5.

`struct.calcsize` (*fmt*)

Return the size of the struct (and hence of the string) corresponding to the given format.

## 7.3.2 Format Strings

Format strings are the mechanism used to specify the expected layout when packing and unpacking data. They are built up from *Format Characters*, which specify the type of data being packed/unpacked. In addition, there are special characters for controlling the *Byte Order, Size, and Alignment*.

### Byte Order, Size, and Alignment

By default, C types are represented in the machine's native format and byte order, and properly aligned by skipping pad bytes if necessary (according to the rules used by the C compiler).

Alternatively, the first character of the format string can be used to indicate the byte order, size and alignment of the packed data, according to the following table:

Character	Byte order	Size	Alignment
@	native	native	native
=	native	standard	none
<	little-endian	standard	none
>	big-endian	standard	none
!	network (= big-endian)	standard	none

If the first character is not one of these, '@' is assumed.

Native byte order is big-endian or little-endian, depending on the host system. For example, Intel x86 and AMD64 (x86-64) are little-endian; Motorola 68000 and PowerPC G5 are big-endian; ARM and Intel Itanium feature switchable endianness (bi-endian). Use `sys.byteorder` to check the endianness of your system.

Native size and alignment are determined using the C compiler's `sizeof` expression. This is always combined with native byte order.

Standard size depends only on the format character; see the table in the *Format Characters* section.

Note the difference between '@' and '=': both use native byte order, but the size and alignment of the latter is standardized.

The form '!' is available for those poor souls who claim they can't remember whether network byte order is big-endian or little-endian.

There is no way to indicate non-native byte order (force byte-swapping); use the appropriate choice of '<' or '>'.

Notes:

1. Padding is only automatically added between successive structure members. No padding is added at the beginning or the end of the encoded struct.
2. No padding is added when using non-native size and alignment, e.g. with '<', '>', '=', and '!'.  
 Note: This is not true for the '=' character. The size and alignment are standardized, but padding is still added between members.
3. To align the end of a structure to the alignment requirement of a particular type, end the format with the code for that type with a repeat count of zero. See *Examples*.

### Format Characters

Format characters have the following meaning; the conversion between C and Python values should be obvious given their types. The 'Standard size' column refers to the size of the packed value in bytes when using standard size; that is, when the format string starts with one of '<', '>', '!' or '='. When using native size, the size of the packed value is platform-dependent.

Format	C Type	Python type	Standard size	Notes
x	pad byte	no value		
c	char	string of length 1	1	
b	signed char	integer	1	(3)
B	unsigned char	integer	1	(3)
?	_Bool	bool	1	(1)
h	short	integer	2	(3)
H	unsigned short	integer	2	(3)
i	int	integer	4	(3)
I	unsigned int	integer	4	(3)
l	long	integer	4	(3)
L	unsigned long	integer	4	(3)
q	long long	integer	8	(2), (3)
Q	unsigned long long	integer	8	(2), (3)
f	float	float	4	(4)
d	double	float	8	(4)
s	char[]	string		
p	char[]	string		
P	void *	integer		(5), (3)

## Notes:

1. The `'?'` conversion code corresponds to the `_Bool` type defined by C99. If this type is not available, it is simulated using a `char`. In standard mode, it is always represented by one byte. New in version 2.6.
2. The `'q'` and `'Q'` conversion codes are available in native mode only if the platform C compiler supports `C long long`, or, on Windows, `__int64`. They are always available in standard modes. New in version 2.2.
3. When attempting to pack a non-integer using any of the integer conversion codes, if the non-integer has a `__index__()` method then that method is called to convert the argument to an integer before packing. If no `__index__()` method exists, or the call to `__index__()` raises `TypeError`, then the `__int__()` method is tried. However, the use of `__int__()` is deprecated, and will raise `DeprecationWarning`. Changed in version 2.7: Use of the `__index__()` method for non-integers is new in 2.7. Changed in version 2.7: Prior to version 2.7, not all integer conversion codes would use the `__int__()` method to convert, and `DeprecationWarning` was raised only for float arguments.
4. For the `'f'` and `'d'` conversion codes, the packed representation uses the IEEE 754 binary32 (for `'f'`) or binary64 (for `'d'`) format, regardless of the floating-point format used by the platform.
5. The `'P'` format character is only available for the native byte ordering (selected as the default or with the `'@'` byte order character). The byte order character `'='` chooses to use little- or big-endian ordering based on the host system. The `struct` module does not interpret this as native ordering, so the `'P'` format is not available.

A format character may be preceded by an integral repeat count. For example, the format string `'4h'` means exactly the same as `'hhhh'`.

Whitespace characters between formats are ignored; a count and its format must not contain whitespace though.

For the `'s'` format character, the count is interpreted as the size of the string, not a repeat count like for the other format characters; for example, `'10s'` means a single 10-byte string, while `'10c'` means 10 characters. If a count is not given, it defaults to 1. For packing, the string is truncated or padded with null bytes as appropriate to make it fit. For unpacking, the resulting string always has exactly the specified number of bytes. As a special case, `'0s'` means a single, empty string (while `'0c'` means 0 characters).

The `'p'` format character encodes a “Pascal string”, meaning a short variable-length string stored in a *fixed number of bytes*, given by the count. The first byte stored is the length of the string, or 255, whichever is smaller. The bytes of the string follow. If the string passed in to `pack()` is too long (longer than the count minus 1), only the leading `count-1` bytes of the string are stored. If the string is shorter than `count-1`, it is padded with null bytes so that

exactly count bytes in all are used. Note that for `unpack()`, the `'p'` format character consumes count bytes, but that the string returned can never contain more than 255 characters.

For the `'P'` format character, the return value is a Python integer or long integer, depending on the size needed to hold a pointer when it has been cast to an integer type. A `NULL` pointer will always be returned as the Python integer 0. When packing pointer-sized values, Python integer or long integer objects may be used. For example, the Alpha and Merced processors use 64-bit pointer values, meaning a Python long integer will be used to hold the pointer; other platforms use 32-bit pointers and will use a Python integer.

For the `'?'` format character, the return value is either `True` or `False`. When packing, the truth value of the argument object is used. Either 0 or 1 in the native or standard bool representation will be packed, and any non-zero value will be `True` when unpacking.

## Examples

**Note:** All examples assume a native byte order, size, and alignment with a big-endian machine.

A basic example of packing/unpacking three integers:

```
>>> from struct import *
>>> pack('hhl', 1, 2, 3)
'\x00\x01\x00\x02\x00\x00\x00\x03'
>>> unpack('hhl', '\x00\x01\x00\x02\x00\x00\x00\x03')
(1, 2, 3)
>>> calcsize('hhl')
8
```

Unpacked fields can be named by assigning them to variables or by wrapping the result in a named tuple:

```
>>> record = 'raymond \x32\x12\x08\x01\x08'
>>> name, serialnum, school, gradelevel = unpack('<10sHHb', record)

>>> from collections import namedtuple
>>> Student = namedtuple('Student', 'name serialnum school gradelevel')
>>> Student._make(unpack('<10sHHb', record))
Student(name='raymond ', serialnum=4658, school=264, gradelevel=8)
```

The ordering of format characters may have an impact on size since the padding needed to satisfy alignment requirements is different:

```
>>> pack('ci', '*', 0x12131415)
'*\x00\x00\x00\x12\x13\x14\x15'
>>> pack('ic', 0x12131415, '*')
'\x12\x13\x14\x15*'
>>> calcsize('ci')
8
>>> calcsize('ic')
5
```

The following format `'llh01'` specifies two pad bytes at the end, assuming longs are aligned on 4-byte boundaries:

```
>>> pack('llh01', 1, 2, 3)
'\x00\x00\x00\x01\x00\x00\x00\x02\x00\x03\x00\x00'
```

This only works when native size and alignment are in effect; standard size and alignment does not enforce any alignment.

**See Also:**

**Module `array`** Packed binary storage of homogeneous data.

**Module `xdrlib`** Packing and unpacking of XDR data.

### 7.3.3 Classes

The `struct` module also defines the following type:

**class** `struct.Struct` (*format*)

Return a new Struct object which writes and reads binary data according to the format string *format*. Creating a Struct object once and calling its methods is more efficient than calling the `struct` functions with the same format since the format string only needs to be compiled once. New in version 2.5. Compiled Struct objects support the following methods and attributes:

**pack** (*v1*, *v2*, ...)

Identical to the `pack()` function, using the compiled format. (`len(result)` will equal `self.size`.)

**pack\_into** (*buffer*, *offset*, *v1*, *v2*, ...)

Identical to the `pack_into()` function, using the compiled format.

**unpack** (*string*)

Identical to the `unpack()` function, using the compiled format. (`len(string)` must equal `self.size`.)

**unpack\_from** (*buffer*, *offset=0*)

Identical to the `unpack_from()` function, using the compiled format. (`len(buffer[offset:])` must be at least `self.size`.)

**format**

The format string used to construct this Struct object.

**size**

The calculated size of the struct (and hence of the string) corresponding to *format*.

## 7.4 `difflib` — Helpers for computing deltas

New in version 2.1. This module provides classes and functions for comparing sequences. It can be used for example, for comparing files, and can produce difference information in various formats, including HTML and context and unified diffs. For comparing directories and files, see also, the `filecmp` module.

**class** `difflib.SequenceMatcher`

This is a flexible class for comparing pairs of sequences of any type, so long as the sequence elements are *hashable*. The basic algorithm predates, and is a little fancier than, an algorithm published in the late 1980's by Ratcliff and Obershelp under the hyperbolic name “gestalt pattern matching.” The idea is to find the longest contiguous matching subsequence that contains no “junk” elements (the Ratcliff and Obershelp algorithm doesn't address junk). The same idea is then applied recursively to the pieces of the sequences to the left and to the right of the matching subsequence. This does not yield minimal edit sequences, but does tend to yield matches that “look right” to people.

**Timing:** The basic Ratcliff-Obershelp algorithm is cubic time in the worst case and quadratic time in the expected case. `SequenceMatcher` is quadratic time for the worst case and has expected-case behavior dependent in a complicated way on how many elements the sequences have in common; best case time is linear.

**Automatic junk heuristic:** `SequenceMatcher` supports a heuristic that automatically treats certain sequence items as junk. The heuristic counts how many times each individual item appears in the sequence. If an item's duplicates (after the first one) account for more than 1% of the sequence and the sequence is at least 200 items long, this item is marked as “popular” and is treated as junk for the purpose of sequence matching. This heuristic

can be turned off by setting the `autojunk` argument to `False` when creating the `SequenceMatcher`. New in version 2.7.1: The `autojunk` parameter.

**class** `difflib.Differ`

This is a class for comparing sequences of lines of text, and producing human-readable differences or deltas. `Differ` uses `SequenceMatcher` both to compare sequences of lines, and to compare sequences of characters within similar (near-matching) lines.

Each line of a `Differ` delta begins with a two-letter code:

Code	Meaning
' - '	line unique to sequence 1
' + '	line unique to sequence 2
' '	line common to both sequences
' ? '	line not present in either input sequence

Lines beginning with '?' attempt to guide the eye to intraline differences, and were not present in either input sequence. These lines can be confusing if the sequences contain tab characters.

**class** `difflib.HtmlDiff`

This class can be used to create an HTML table (or a complete HTML file containing the table) showing a side by side, line by line comparison of text with inter-line and intra-line change highlights. The table can be generated in either full or contextual difference mode.

The constructor for this class is:

`__init__` (*tabsize=8, wrapcolumn=None, linejunk=None, charjunk=IS\_CHARACTER\_JUNK*)

Initializes instance of `HtmlDiff`.

*tabsize* is an optional keyword argument to specify tab stop spacing and defaults to 8.

*wrapcolumn* is an optional keyword to specify column number where lines are broken and wrapped, defaults to `None` where lines are not wrapped.

*linejunk* and *charjunk* are optional keyword arguments passed into `ndiff()` (used by `HtmlDiff` to generate the side by side HTML differences). See `ndiff()` documentation for argument default values and descriptions.

The following methods are public:

**make\_file** (*fromlines, tolines* [, *fromdesc*][, *todesc*][, *context*][, *numlines*])

Compares *fromlines* and *tolines* (lists of strings) and returns a string which is a complete HTML file containing a table showing line by line differences with inter-line and intra-line changes highlighted.

*fromdesc* and *todesc* are optional keyword arguments to specify from/to file column header strings (both default to an empty string).

*context* and *numlines* are both optional keyword arguments. Set *context* to `True` when contextual differences are to be shown, else the default is `False` to show the full files. *numlines* defaults to 5. When *context* is `True` *numlines* controls the number of context lines which surround the difference highlights. When *context* is `False` *numlines* controls the number of lines which are shown before a difference highlight when using the "next" hyperlinks (setting to zero would cause the "next" hyperlinks to place the next difference highlight at the top of the browser without any leading context).

**make\_table** (*fromlines, tolines* [, *fromdesc*][, *todesc*][, *context*][, *numlines*])

Compares *fromlines* and *tolines* (lists of strings) and returns a string which is a complete HTML table showing line by line differences with inter-line and intra-line changes highlighted.

The arguments for this method are the same as those for the `make_file()` method.

`Tools/scripts/diff.py` is a command-line front-end to this class and contains a good example of its use. New in version 2.4.

`diff`lib.**context\_diff**(*a*, *b*[, *fromfile*][, *tofile*][, *fromfiledate*][, *tofiledate*][, *n*][, *lineterm*])

Compare *a* and *b* (lists of strings); return a delta (a *generator* generating the delta lines) in context diff format.

Context diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in a before/after style. The number of context lines is set by *n* which defaults to three.

By default, the diff control lines (those with `***` or `---`) are created with a trailing newline. This is helpful so that inputs created from `file.readlines()` result in diffs that are suitable for use with `file.writelines()` since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the *lineterm* argument to `" "` so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for *fromfile*, *tofile*, *fromfiledate*, and *tofiledate*. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n']
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'guido\n']
>>> for line in context_diff(s1, s2, fromfile='before.py', tofile='after.py'):
...     sys.stdout.write(line)
*** before.py
--- after.py
*****
*** 1,4 ****
! bacon
! eggs
! ham
! guido
--- 1,4 ----
! python
! eggy
! hamster
! guido
```

See *A command-line interface to diff*lib for a more detailed example. New in version 2.3.

`diff`lib.**get\_close\_matches**(*word*, *possibilities*[, *n*][, *cutoff*])

Return a list of the best “good enough” matches. *word* is a sequence for which close matches are desired (typically a string), and *possibilities* is a list of sequences against which to match *word* (typically a list of strings).

Optional argument *n* (default 3) is the maximum number of close matches to return; *n* must be greater than 0.

Optional argument *cutoff* (default 0.6) is a float in the range [0, 1]. Possibilities that don’t score at least that similar to *word* are ignored.

The best (no more than *n*) matches among the possibilities are returned in a list, sorted by similarity score, most similar first.

```
>>> get_close_matches('appel', ['ape', 'apple', 'peach', 'puppy'])
['apple', 'ape']
>>> import keyword
>>> get_close_matches('wheel', keyword.kwlist)
['while']
>>> get_close_matches('apple', keyword.kwlist)
[]
```

```
>>> get_close_matches('accept', keyword.kwlist)
['except']
```

`difflib.ndiff(a, b[, linejunk][, charjunk])`

Compare *a* and *b* (lists of strings); return a *Differ*-style delta (a *generator* generating the delta lines).

Optional keyword parameters *linejunk* and *charjunk* are for filter functions (or `None`):

*linejunk*: A function that accepts a single string argument, and returns true if the string is junk, or false if not. The default is (`None`), starting with Python 2.3. Before then, the default was the module-level function `IS_LINE_JUNK()`, which filters out lines without visible characters, except for at most one pound character (`'#'`). As of Python 2.3, the underlying `SequenceMatcher` class does a dynamic analysis of which lines are so frequent as to constitute noise, and this usually works better than the pre-2.3 default.

*charjunk*: A function that accepts a character (a string of length 1), and returns if the character is junk, or false if not. The default is module-level function `IS_CHARACTER_JUNK()`, which filters out whitespace characters (a blank or tab; note: bad idea to include newline in this!).

`Tools/scripts/ndiff.py` is a command-line front-end to this function.

```
>>> diff = ndiff('one\ntwo\nthree\n'.splitlines(1),
...             'ore\ntree\nemu\n'.splitlines(1))
>>> print ''.join(diff),
- one
? ^
+ ore
? ^
- two
- three
? -
+ tree
+ emu
```

`difflib.restore(sequence, which)`

Return one of the two sequences that generated a delta.

Given a *sequence* produced by `Differ.compare()` or `ndiff()`, extract lines originating from file 1 or 2 (parameter *which*), stripping off line prefixes.

Example:

```
>>> diff = ndiff('one\ntwo\nthree\n'.splitlines(1),
...             'ore\ntree\nemu\n'.splitlines(1))
>>> diff = list(diff) # materialize the generated delta into a list
>>> print ''.join	restore(diff, 1)),
one
two
three
>>> print ''.join	restore(diff, 2)),
ore
tree
emu
```

`difflib.unified_diff(a, b[, fromfile][, tofile][, fromfiledate][, tofiledate][, n][, lineterm])`

Compare *a* and *b* (lists of strings); return a delta (a *generator* generating the delta lines) in unified diff format.

Unified diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in an inline style (instead of separate before/after blocks). The number of context lines is set by *n* which defaults to three.

By default, the diff control lines (those with ---, +++, or @@) are created with a trailing newline. This is helpful so that inputs created from `file.readlines()` result in diffs that are suitable for use with `file.writelines()` since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the `lineterm` argument to "" so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for `fromfile`, `tofile`, `fromfiledate`, and `tofiledate`. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n']
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'guido\n']
>>> for line in unified_diff(s1, s2, fromfile='before.py', tofile='after.py'):
...     sys.stdout.write(line)
--- before.py
+++ after.py
@@ -1,4 +1,4 @@
-bacon
-eggs
-ham
+python
+eggy
+hamster
  guido
```

See *A command-line interface to difflib* for a more detailed example. New in version 2.3.

`difflib.IS_LINE_JUNK` (*line*)

Return true for ignorable lines. The line *line* is ignorable if *line* is blank or contains a single '#', otherwise it is not ignorable. Used as a default for parameter `linejunk` in `ndiff()` before Python 2.3.

`difflib.IS_CHARACTER_JUNK` (*ch*)

Return true for ignorable characters. The character *ch* is ignorable if *ch* is a space or tab, otherwise it is not ignorable. Used as a default for parameter `charjunk` in `ndiff()`.

**See Also:**

**Pattern Matching: The Gestalt Approach** Discussion of a similar algorithm by John W. Ratcliff and D. E. Metzener. This was published in *Dr. Dobbs's Journal* in July, 1988.

## 7.4.1 SequenceMatcher Objects

The `SequenceMatcher` class has this constructor:

```
class difflib.SequenceMatcher (isjunk=None, a='', b='', autojunk=True)
```

Optional argument `isjunk` must be `None` (the default) or a one-argument function that takes a sequence element and returns true if and only if the element is “junk” and should be ignored. Passing `None` for `isjunk` is equivalent to passing `lambda x: x == 0`; in other words, no elements are ignored. For example, pass:

```
lambda x: x in " \t"
```

if you're comparing lines as sequences of characters, and don't want to synch up on blanks or hard tabs.

The optional arguments *a* and *b* are sequences to be compared; both default to empty strings. The elements of both sequences must be *hashable*.

The optional argument *autojunk* can be used to disable the automatic junk heuristic. New in version 2.7.1: The *autojunk* parameter. `SequenceMatcher` objects have the following methods:

**set\_seqs** (*a*, *b*)

Set the two sequences to be compared.

`SequenceMatcher` computes and caches detailed information about the second sequence, so if you want to compare one sequence against many sequences, use `set_seq2()` to set the commonly used sequence once and call `set_seq1()` repeatedly, once for each of the other sequences.

**set\_seq1** (*a*)

Set the first sequence to be compared. The second sequence to be compared is not changed.

**set\_seq2** (*b*)

Set the second sequence to be compared. The first sequence to be compared is not changed.

**find\_longest\_match** (*alo*, *ahi*, *blo*, *bhi*)

Find longest matching block in `a[alo:ahi]` and `b[blo:bhi]`.

If *isjunk* was omitted or `None`, `find_longest_match()` returns (*i*, *j*, *k*) such that `a[i:i+k]` is equal to `b[j:j+k]`, where `alo <= i <= i+k <= ahi` and `blo <= j <= j+k <= bhi`. For all (*i'*, *j'*, *k'*) meeting those conditions, the additional conditions `k >= k'`, `i <= i'`, and if `i == i'`, `j <= j'` are also met. In other words, of all maximal matching blocks, return one that starts earliest in *a*, and of all those maximal matching blocks that start earliest in *a*, return the one that starts earliest in *b*.

```
>>> s = SequenceMatcher(None, "abcd", "abcd abcd")
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=0, b=4, size=5)
```

If *isjunk* was provided, first the longest matching block is determined as above, but with the additional restriction that no junk element appears in the block. Then that block is extended as far as possible by matching (only) junk elements on both sides. So the resulting block never matches on junk except as identical junk happens to be adjacent to an interesting match.

Here's the same example as before, but considering blanks to be junk. That prevents 'abcd' from matching the 'abcd' at the tail end of the second sequence directly. Instead only the 'abcd' can match, and matches the leftmost 'abcd' in the second sequence:

```
>>> s = SequenceMatcher(lambda x: x==" ", "abcd", "abcd abcd")
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=1, b=0, size=4)
```

If no blocks match, this returns (*alo*, *blo*, 0). Changed in version 2.6: This method returns a *named tuple* `Match(a, b, size)`.

**get\_matching\_blocks** ()

Return list of triples describing matching subsequences. Each triple is of the form (*i*, *j*, *n*), and means that `a[i:i+n] == b[j:j+n]`. The triples are monotonically increasing in *i* and *j*.

The last triple is a dummy, and has the value `(len(a), len(b), 0)`. It is the only triple with `n == 0`. If (*i*, *j*, *n*) and (*i'*, *j'*, *n'*) are adjacent triples in the list, and the second is not the last triple in the list, then `i+n != i'` or `j+n != j'`; in other words, adjacent triples always describe non-adjacent equal blocks. Changed in version 2.5: The guarantee that adjacent triples always describe non-adjacent blocks was implemented.

```
>>> s = SequenceMatcher(None, "abxcd", "abcd")
>>> s.get_matching_blocks()
[Match(a=0, b=0, size=2), Match(a=3, b=2, size=2), Match(a=5, b=4, size=0)]
```

**get\_opcodes()**

Return list of 5-tuples describing how to turn *a* into *b*. Each tuple is of the form (tag, i1, i2, j1, j2). The first tuple has i1 == j1 == 0, and remaining tuples have i1 equal to the i2 from the preceding tuple, and, likewise, j1 equal to the previous j2.

The tag values are strings, with these meanings:

Value	Meaning
'replace'	a[i1:i2] should be replaced by b[j1:j2].
'delete'	a[i1:i2] should be deleted. Note that j1 == j2 in this case.
'insert'	b[j1:j2] should be inserted at a[i1:i1]. Note that i1 == i2 in this case.
'equal'	a[i1:i2] == b[j1:j2] (the sub-sequences are equal).

For example:

```
>>> a = "qabxcd"
>>> b = "abycdf"
>>> s = SequenceMatcher(None, a, b)
>>> for tag, i1, i2, j1, j2 in s.get_opcodes():
...     print ("%7s a[%d:%d] (%s) b[%d:%d] (%s)" %
...           (tag, i1, i2, a[i1:i2], j1, j2, b[j1:j2]))
delete a[0:1] (q) b[0:0] ()
equal a[1:3] (ab) b[0:2] (ab)
replace a[3:4] (x) b[2:3] (y)
equal a[4:6] (cd) b[3:5] (cd)
insert a[6:6] () b[5:6] (f)
```

**get\_grouped\_opcodes([n])**

Return a generator of groups with up to *n* lines of context.

Starting with the groups returned by `get_opcodes()`, this method splits out smaller change clusters and eliminates intervening ranges which have no changes.

The groups are returned in the same format as `get_opcodes()`. New in version 2.3.

**ratio()**

Return a measure of the sequences' similarity as a float in the range [0, 1].

Where T is the total number of elements in both sequences, and M is the number of matches, this is 2.0\*M / T. Note that this is 1.0 if the sequences are identical, and 0.0 if they have nothing in common.

This is expensive to compute if `get_matching_blocks()` or `get_opcodes()` hasn't already been called, in which case you may want to try `quick_ratio()` or `real_quick_ratio()` first to get an upper bound.

**quick\_ratio()**

Return an upper bound on `ratio()` relatively quickly.

**real\_quick\_ratio()**

Return an upper bound on `ratio()` very quickly.

The three methods that return the ratio of matching to total characters can give different results due to differing levels of approximation, although `quick_ratio()` and `real_quick_ratio()` are always at least as large as `ratio()`:

```
>>> s = SequenceMatcher(None, "abcd", "bcde")
>>> s.ratio()
```

```
0.75
>>> s.quick_ratio()
0.75
>>> s.real_quick_ratio()
1.0
```

## 7.4.2 SequenceMatcher Examples

This example compares two strings, considering blanks to be “junk:”

```
>>> s = SequenceMatcher(lambda x: x == " ",
...                       "private Thread currentThread;",
...                       "private volatile Thread currentThread;")
```

`ratio()` returns a float in  $[0, 1]$ , measuring the similarity of the sequences. As a rule of thumb, a `ratio()` value over 0.6 means the sequences are close matches:

```
>>> print round(s.ratio(), 3)
0.866
```

If you’re only interested in where the sequences match, `get_matching_blocks()` is handy:

```
>>> for block in s.get_matching_blocks():
...     print "a[%d] and b[%d] match for %d elements" % block
a[0] and b[0] match for 8 elements
a[8] and b[17] match for 21 elements
a[29] and b[38] match for 0 elements
```

Note that the last tuple returned by `get_matching_blocks()` is always a dummy, `(len(a), len(b), 0)`, and this is the only case in which the last tuple element (number of elements matched) is 0.

If you want to know how to change the first sequence into the second, use `get_opcodes()`:

```
>>> for opcode in s.get_opcodes():
...     print "%6s a[%d:%d] b[%d:%d]" % opcode
equal a[0:8] b[0:8]
insert a[8:8] b[8:17]
equal a[8:29] b[17:38]
```

### See Also:

- The `get_close_matches()` function in this module which shows how simple code building on `SequenceMatcher` can be used to do useful work.
- [Simple version control recipe](#) for a small application built with `SequenceMatcher`.

## 7.4.3 Differ Objects

Note that `Differ`-generated deltas make no claim to be **minimal** diffs. To the contrary, minimal diffs are often counter-intuitive, because they synch up anywhere possible, sometimes accidental matches 100 pages apart. Restricting synch points to contiguous matches preserves some notion of locality, at the occasional cost of producing a longer diff.

The `Differ` class has this constructor:

```
class difflib.Differ([linejunk[, charjunk]])
    Optional keyword parameters linejunk and charjunk are for filter functions (or None):
```

*linejunk*: A function that accepts a single string argument, and returns true if the string is junk. The default is None, meaning that no line is considered junk.

*charjunk*: A function that accepts a single character argument (a string of length 1), and returns true if the character is junk. The default is None, meaning that no character is considered junk.

`Differ` objects are used (deltas generated) via a single method:

**compare** (*a*, *b*)

Compare two sequences of lines, and generate the delta (a sequence of lines).

Each sequence must contain individual single-line strings ending with newlines. Such sequences can be obtained from the `readlines()` method of file-like objects. The delta generated also consists of newline-terminated strings, ready to be printed as-is via the `writelines()` method of a file-like object.

### 7.4.4 Differ Example

This example compares two texts. First we set up the texts, sequences of individual single-line strings ending with newlines (such sequences can also be obtained from the `readlines()` method of file-like objects):

```
>>> text1 = ''' 1. Beautiful is better than ugly.
... 2. Explicit is better than implicit.
... 3. Simple is better than complex.
... 4. Complex is better than complicated.
... '''.splitlines(1)
>>> len(text1)
4
>>> text1[0][-1]
'\n'
>>> text2 = ''' 1. Beautiful is better than ugly.
... 3. Simple is better than complex.
... 4. Complicated is better than complex.
... 5. Flat is better than nested.
... '''.splitlines(1)
```

Next we instantiate a `Differ` object:

```
>>> d = Differ()
```

Note that when instantiating a `Differ` object we may pass functions to filter out line and character “junk.” See the `Differ()` constructor for details.

Finally, we compare the two:

```
>>> result = list(d.compare(text1, text2))
```

result is a list of strings, so let’s pretty-print it:

```
>>> from pprint import pprint
>>> pprint(result)
[' 1. Beautiful is better than ugly.\n',
'- 2. Explicit is better than implicit.\n',
'- 3. Simple is better than complex.\n',
'+ 3. Simple is better than complex.\n',
'? ++\n',
'- 4. Complex is better than complicated.\n',
'? ^ ---- ^\n',
'+ 4. Complicated is better than complex.\n',
```

```
'?          +++++ ^                ^\n',
'+  5. Flat is better than nested.\n']
```

As a single multi-line string it looks like this:

```
>>> import sys
>>> sys.stdout.writelines(result)
1. Beautiful is better than ugly.
- 2. Explicit is better than implicit.
- 3. Simple is better than complex.
+ 3.   Simple is better than complex.
?   ++
- 4. Complex is better than complicated.
?   ^                ----- ^
+ 4. Complicated is better than complex.
?   +++++ ^                ^
+ 5. Flat is better than nested.
```

## 7.4.5 A command-line interface to difflib

This example shows how to use difflib to create a diff-like utility. It is also contained in the Python source distribution, as `Tools/scripts/diff.py`.

```
""" Command line interface to difflib.py providing diffs in four formats:
```

```
* ndiff:    lists every line and highlights interline changes.
* context:  highlights clusters of changes in a before/after format.
* unified:  highlights clusters of changes in an inline format.
* html:     generates side by side comparison with change highlights.
```

```
"""
```

```
import sys, os, time, difflib, optparse
```

```
def main():
    # Configure the option parser
    usage = "usage: %prog [options] fromfile tofile"
    parser = optparse.OptionParser(usage)
    parser.add_option("-c", action="store_true", default=False,
                    help='Produce a context format diff (default)')
    parser.add_option("-u", action="store_true", default=False,
                    help='Produce a unified format diff')
    hlp = 'Produce HTML side by side diff (can use -c and -l in conjunction)'
    parser.add_option("-m", action="store_true", default=False, help=hlp)
    parser.add_option("-n", action="store_true", default=False,
                    help='Produce a ndiff format diff')
    parser.add_option("-l", "--lines", type="int", default=3,
                    help='Set number of context lines (default 3)')
    (options, args) = parser.parse_args()

    if len(args) == 0:
        parser.print_help()
        sys.exit(1)
    if len(args) != 2:
        parser.error("need to specify both a fromfile and tofile")
```

```
n = options.lines
fromfile, tofile = args # as specified in the usage string

# we're passing these as arguments to the diff function
fromdate = time.ctime(os.stat(fromfile).st_mtime)
todate = time.ctime(os.stat(tofile).st_mtime)
fromlines = open(fromfile, 'U').readlines()
tolines = open(tofile, 'U').readlines()

if options.u:
    diff = difflib.unified_diff(fromlines, tolines, fromfile, tofile,
                               fromdate, todate, n=n)

elif options.n:
    diff = difflib.ndiff(fromlines, tolines)

elif options.m:
    diff = difflib.HtmlDiff().make_file(fromlines, tolines, fromfile,
                                       tofile, context=options.c,
                                       numlines=n)

else:
    diff = difflib.context_diff(fromlines, tolines, fromfile, tofile,
                               fromdate, todate, n=n)

# we're using writelines because diff is a generator
sys.stdout.writelines(diff)

if __name__ == '__main__':
    main()
```

## 7.5 StringIO — Read and write strings as files

This module implements a file-like class, `StringIO`, that reads and writes a string buffer (also known as *memory files*). See the description of file objects for operations (section *File Objects*). (For standard strings, see `str` and `unicode`.)

**class** `StringIO.StringIO([buffer])`

When a `StringIO` object is created, it can be initialized to an existing string by passing the string to the constructor. If no string is given, the `StringIO` will start empty. In both cases, the initial file position starts at zero.

The `StringIO` object can accept either Unicode or 8-bit strings, but mixing the two may take some care. If both are used, 8-bit strings that cannot be interpreted as 7-bit ASCII (that use the 8th bit) will cause a `UnicodeError` to be raised when `getvalue()` is called.

The following methods of `StringIO` objects require special mention:

`StringIO.getvalue()`

Retrieve the entire contents of the “file” at any time before the `StringIO` object’s `close()` method is called. See the note above for information about mixing Unicode and 8-bit strings; such mixing can cause this method to raise `UnicodeError`.

`StringIO.close()`

Free the memory buffer. Attempting to do further operations with a closed `StringIO` object will raise a `ValueError`.

Example usage:

```
import StringIO

output = StringIO.StringIO()
output.write('First line.\n')
print >>output, 'Second line.'

# Retrieve file contents -- this will be
# 'First line.\nSecond line.\n'
contents = output.getvalue()

# Close object and discard memory buffer --
# .getvalue() will now raise an exception.
output.close()
```

## 7.6 cStringIO — Faster version of StringIO

The module `cStringIO` provides an interface similar to that of the `StringIO` module. Heavy use of `StringIO.StringIO` objects can be made more efficient by using the function `StringIO()` from this module instead.

`cStringIO.StringIO([s])`

Return a StringIO-like stream for reading or writing.

Since this is a factory function which returns objects of built-in types, there's no way to build your own version using subclassing. It's not possible to set attributes on it. Use the original `StringIO` module in those cases.

Unlike the `StringIO` module, this module is not able to accept Unicode strings that cannot be encoded as plain ASCII strings.

Another difference from the `StringIO` module is that calling `StringIO()` with a string parameter creates a read-only object. Unlike an object created without a string parameter, it does not have write methods. These objects are not generally visible. They turn up in tracebacks as `StringI` and `StringO`.

The following data objects are provided as well:

`cStringIO.InputType`

The type object of the objects created by calling `StringIO()` with a string parameter.

`cStringIO.OutputType`

The type object of the objects returned by calling `StringIO()` with no parameters.

There is a C API to the module as well; refer to the module source for more information.

Example usage:

```
import cStringIO

output = cStringIO.StringIO()
output.write('First line.\n')
print >>output, 'Second line.'

# Retrieve file contents -- this will be
# 'First line.\nSecond line.\n'
contents = output.getvalue()

# Close object and discard memory buffer --
```

```
# .getvalue() will now raise an exception.  
output.close()
```

## 7.7 textwrap — Text wrapping and filling

New in version 2.3. **Source code:** [Lib/textwrap.py](#)

---

The `textwrap` module provides two convenience functions, `wrap()` and `fill()`, as well as `TextWrapper`, the class that does all the work, and a utility function `dedent()`. If you're just wrapping or filling one or two text strings, the convenience functions should be good enough; otherwise, you should use an instance of `TextWrapper` for efficiency.

`textwrap.wrap(text[, width[, ...]])`

Wraps the single paragraph in `text` (a string) so every line is at most `width` characters long. Returns a list of output lines, without final newlines.

Optional keyword arguments correspond to the instance attributes of `TextWrapper`, documented below. `width` defaults to 70.

See the `TextWrapper.wrap()` method for additional details on how `wrap()` behaves.

`textwrap.fill(text[, width[, ...]])`

Wraps the single paragraph in `text`, and returns a single string containing the wrapped paragraph. `fill()` is shorthand for

```
"\n".join(wrap(text, ...))
```

In particular, `fill()` accepts exactly the same keyword arguments as `wrap()`.

Both `wrap()` and `fill()` work by creating a `TextWrapper` instance and calling a single method on it. That instance is not reused, so for applications that wrap/fill many text strings, it will be more efficient for you to create your own `TextWrapper` object.

Text is preferably wrapped on whitespaces and right after the hyphens in hyphenated words; only then will long words be broken if necessary, unless `TextWrapper.break_long_words` is set to false.

An additional utility function, `dedent()`, is provided to remove indentation from strings that have unwanted whitespace to the left of the text.

`textwrap.dedent(text)`

Remove any common leading whitespace from every line in `text`.

This can be used to make triple-quoted strings line up with the left edge of the display, while still presenting them in the source code in indented form.

Note that tabs and spaces are both treated as whitespace, but they are not equal: the lines `" hello"` and `"\thello"` are considered to have no common leading whitespace. (This behaviour is new in Python 2.5; older versions of this module incorrectly expanded tabs before searching for common leading whitespace.)

For example:

```
def test():  
    # end first line with \ to avoid the empty line!  
    s = '''\  
hello  
    world  
'''
```

```
print repr(s)           # prints '  hello\n      world\n  '
print repr(dedent(s))  # prints 'hello\n world\n'
```

**class** `textwrap.TextWrapper(...)`

The `TextWrapper` constructor accepts a number of optional keyword arguments. Each argument corresponds to one instance attribute, so for example

```
wrapper = TextWrapper(initial_indent="* ")
```

is the same as

```
wrapper = TextWrapper()
wrapper.initial_indent = "* "
```

You can re-use the same `TextWrapper` object many times, and you can change any of its options through direct assignment to instance attributes between uses.

The `TextWrapper` instance attributes (and keyword arguments to the constructor) are as follows:

#### **width**

(default: 70) The maximum length of wrapped lines. As long as there are no individual words in the input text longer than `width`, `TextWrapper` guarantees that no output line will be longer than `width` characters.

#### **expand\_tabs**

(default: `True`) If true, then all tab characters in `text` will be expanded to spaces using the `expandtabs()` method of `text`.

#### **replace\_whitespace**

(default: `True`) If true, after tab expansion but before wrapping, the `wrap()` method will replace each whitespace character with a single space. The whitespace characters replaced are as follows: tab, newline, vertical tab, formfeed, and carriage return (`'\t\n\v\f\r'`).

---

**Note:** If `expand_tabs` is false and `replace_whitespace` is true, each tab character will be replaced by a single space, which is *not* the same as tab expansion.

---

**Note:** If `replace_whitespace` is false, newlines may appear in the middle of a line and cause strange output. For this reason, text should be split into paragraphs (using `str.splitlines()` or similar) which are wrapped separately.

---

#### **drop\_whitespace**

(default: `True`) If true, whitespace at the beginning and ending of every line (after wrapping but before indenting) is dropped. Whitespace at the beginning of the paragraph, however, is not dropped if non-whitespace follows it. If whitespace being dropped takes up an entire line, the whole line is dropped. New in version 2.6: Whitespace was always dropped in earlier versions.

#### **initial\_indent**

(default: `''`) String that will be prepended to the first line of wrapped output. Counts towards the length of the first line. The empty string is not indented.

#### **subsequent\_indent**

(default: `''`) String that will be prepended to all lines of wrapped output except the first. Counts towards the length of each line except the first.

**fix\_sentence\_endings**

(default: `False`) If true, `TextWrapper` attempts to detect sentence endings and ensure that sentences are always separated by exactly two spaces. This is generally desired for text in a monospaced font. However, the sentence detection algorithm is imperfect: it assumes that a sentence ending consists of a lowercase letter followed by one of `'.'`, `'!'`, or `'?'`, possibly followed by one of `'\"'` or `'\"'`, followed by a space. One problem with this algorithm is that it is unable to detect the difference between “Dr.” in

```
[...] Dr. Frankenstein's monster [...]
```

and “Spot.” in

```
[...] See Spot. See Spot run [...]
```

`fix_sentence_endings` is false by default.

Since the sentence detection algorithm relies on `string.lowercase` for the definition of “lowercase letter,” and a convention of using two spaces after a period to separate sentences on the same line, it is specific to English-language texts.

**break\_long\_words**

(default: `True`) If true, then words longer than `width` will be broken in order to ensure that no lines are longer than `width`. If it is false, long words will not be broken, and some lines may be longer than `width`. (Long words will be put on a line by themselves, in order to minimize the amount by which `width` is exceeded.)

**break\_on\_hyphens**

(default: `True`) If true, wrapping will occur preferably on whitespaces and right after hyphens in compound words, as it is customary in English. If false, only whitespaces will be considered as potentially good places for line breaks, but you need to set `break_long_words` to false if you want truly insecable words. Default behaviour in previous versions was to always allow breaking hyphenated words. New in version 2.6.

`TextWrapper` also provides two public methods, analogous to the module-level convenience functions:

**wrap** (*text*)

Wraps the single paragraph in *text* (a string) so every line is at most `width` characters long. All wrapping options are taken from instance attributes of the `TextWrapper` instance. Returns a list of output lines, without final newlines. If the wrapped output has no content, the returned list is empty.

**fill** (*text*)

Wraps the single paragraph in *text*, and returns a single string containing the wrapped paragraph.

## 7.8 codecs — Codec registry and base classes

This module defines base classes for standard Python codecs (encoders and decoders) and provides access to the internal Python codec registry which manages the codec and error handling lookup process.

It defines the following functions:

**codecs.register** (*search\_function*)

Register a codec search function. Search functions are expected to take one argument, the encoding name in all lower case letters, and return a `CodecInfo` object having the following attributes:

- `name` The name of the encoding;
- `encode` The stateless encoding function;
- `decode` The stateless decoding function;

- `incrementalencoder` An incremental encoder class or factory function;
- `incrementaldecoder` An incremental decoder class or factory function;
- `streamwriter` A stream writer class or factory function;
- `streamreader` A stream reader class or factory function.

The various functions or classes take the following arguments:

*encode* and *decode*: These must be functions or methods which have the same interface as the `encode()/decode()` methods of Codec instances (see Codec Interface). The functions/methods are expected to work in a stateless mode.

*incrementalencoder* and *incrementaldecoder*: These have to be factory functions providing the following interface:

```
factory(errors='strict')
```

The factory functions must return objects providing the interfaces defined by the base classes `IncrementalEncoder` and `IncrementalDecoder`, respectively. Incremental codecs can maintain state.

*streamreader* and *streamwriter*: These have to be factory functions providing the following interface:

```
factory(stream, errors='strict')
```

The factory functions must return objects providing the interfaces defined by the base classes `StreamWriter` and `StreamReader`, respectively. Stream codecs can maintain state.

Possible values for errors are

- `'strict'`: raise an exception in case of an encoding error
- `'replace'`: replace malformed data with a suitable replacement marker, such as `'?'` or `'\ufffd'`
- `'ignore'`: ignore malformed data and continue without further notice
- `'xmlcharrefreplace'`: replace with the appropriate XML character reference (for encoding only)
- `'backslashreplace'`: replace with backslashed escape sequences (for encoding only)

as well as any other error handling name defined via `register_error()`.

In case a search function cannot find a given encoding, it should return `None`.

`codecs.lookup(encoding)`

Looks up the codec info in the Python codec registry and returns a `CodecInfo` object as defined above.

Encodings are first looked up in the registry's cache. If not found, the list of registered search functions is scanned. If no `CodecInfo` object is found, a `LookupError` is raised. Otherwise, the `CodecInfo` object is stored in the cache and returned to the caller.

To simplify access to the various codecs, the module provides these additional functions which use `lookup()` for the codec lookup:

`codecs.getencoder(encoding)`

Look up the codec for the given encoding and return its encoder function.

Raises a `LookupError` in case the encoding cannot be found.

`codecs.getdecoder(encoding)`

Look up the codec for the given encoding and return its decoder function.

Raises a `LookupError` in case the encoding cannot be found.

`codecs.getincrementalencoder` (*encoding*)

Look up the codec for the given encoding and return its incremental encoder class or factory function.

Raises a `LookupError` in case the encoding cannot be found or the codec doesn't support an incremental encoder. New in version 2.5.

`codecs.getincrementaldecoder` (*encoding*)

Look up the codec for the given encoding and return its incremental decoder class or factory function.

Raises a `LookupError` in case the encoding cannot be found or the codec doesn't support an incremental decoder. New in version 2.5.

`codecs.getreader` (*encoding*)

Look up the codec for the given encoding and return its `StreamReader` class or factory function.

Raises a `LookupError` in case the encoding cannot be found.

`codecs.getwriter` (*encoding*)

Look up the codec for the given encoding and return its `StreamWriter` class or factory function.

Raises a `LookupError` in case the encoding cannot be found.

`codecs.register_error` (*name*, *error\_handler*)

Register the error handling function *error\_handler* under the name *name*. *error\_handler* will be called during encoding and decoding in case of an error, when *name* is specified as the errors parameter.

For encoding *error\_handler* will be called with a `UnicodeEncodeError` instance, which contains information about the location of the error. The error handler must either raise this or a different exception or return a tuple with a replacement for the unencodable part of the input and a position where encoding should continue. The encoder will encode the replacement and continue encoding the original input at the specified position. Negative position values will be treated as being relative to the end of the input string. If the resulting position is out of bound an `IndexError` will be raised.

Decoding and translating works similar, except `UnicodeDecodeError` or `UnicodeTranslateError` will be passed to the handler and that the replacement from the error handler will be put into the output directly.

`codecs.lookup_error` (*name*)

Return the error handler previously registered under the name *name*.

Raises a `LookupError` in case the handler cannot be found.

`codecs.strict_errors` (*exception*)

Implements the `strict` error handling: each encoding or decoding error raises a `UnicodeError`.

`codecs.replace_errors` (*exception*)

Implements the `replace` error handling: malformed data is replaced with a suitable replacement character such as '?' in bytestrings and '\ufffd' in Unicode strings.

`codecs.ignore_errors` (*exception*)

Implements the `ignore` error handling: malformed data is ignored and encoding or decoding is continued without further notice.

`codecs.xmlcharrefreplace_errors` (*exception*)

Implements the `xmlcharrefreplace` error handling (for encoding only): the unencodable character is replaced by an appropriate XML character reference.

`codecs.backslashreplace_errors` (*exception*)

Implements the `backslashreplace` error handling (for encoding only): the unencodable character is replaced by a backslashed escape sequence.

To simplify working with encoded files or stream, the module also defines these utility functions:

`codecs.open(filename, mode[, encoding[, errors[, buffering]]])`

Open an encoded file using the given *mode* and return a wrapped version providing transparent encoding/decoding. The default file mode is 'r' meaning to open the file in read mode.

---

**Note:** The wrapped version will only accept the object format defined by the codecs, i.e. Unicode objects for most built-in codecs. Output is also codec-dependent and will usually be Unicode as well.

---

**Note:** Files are always opened in binary mode, even if no binary mode was specified. This is done to avoid data loss due to encodings using 8-bit values. This means that no automatic conversion of '\n' is done on reading and writing.

---

*encoding* specifies the encoding which is to be used for the file.

*errors* may be given to define the error handling. It defaults to 'strict' which causes a `ValueError` to be raised in case an encoding error occurs.

*buffering* has the same meaning as for the built-in `open()` function. It defaults to line buffered.

`codecs.EncodedFile(file, input[, output[, errors]])`

Return a wrapped version of file which provides transparent encoding translation.

Strings written to the wrapped file are interpreted according to the given *input* encoding and then written to the original file as strings using the *output* encoding. The intermediate encoding will usually be Unicode but depends on the specified codecs.

If *output* is not given, it defaults to *input*.

*errors* may be given to define the error handling. It defaults to 'strict', which causes `ValueError` to be raised in case an encoding error occurs.

`codecs.iterencode(iterable, encoding[, errors])`

Uses an incremental encoder to iteratively encode the input provided by *iterable*. This function is a *generator*. *errors* (as well as any other keyword argument) is passed through to the incremental encoder. New in version 2.5.

`codecs.iterdecode(iterable, encoding[, errors])`

Uses an incremental decoder to iteratively decode the input provided by *iterable*. This function is a *generator*. *errors* (as well as any other keyword argument) is passed through to the incremental decoder. New in version 2.5.

The module also provides the following constants which are useful for reading and writing to platform dependent files:

`codecs.BOM`

`codecs.BOM_BE`

`codecs.BOM_LE`

`codecs.BOM_UTF8`

`codecs.BOM_UTF16`

`codecs.BOM_UTF16_BE`

`codecs.BOM_UTF16_LE`

`codecs.BOM_UTF32`

`codecs.BOM_UTF32_BE`

`codecs.BOM_UTF32_LE`

These constants define various encodings of the Unicode byte order mark (BOM) used in UTF-16 and UTF-32 data streams to indicate the byte order used in the stream or file and in UTF-8 as a Unicode signature. `BOM_UTF16` is either `BOM_UTF16_BE` or `BOM_UTF16_LE` depending on the platform's native byte order, `BOM` is an alias for `BOM_UTF16`, `BOM_LE` for `BOM_UTF16_LE` and `BOM_BE` for `BOM_UTF16_BE`. The others represent the BOM in UTF-8 and UTF-32 encodings.

## 7.8.1 Codec Base Classes

The `codecs` module defines a set of base classes which define the interface and can also be used to easily write your own codecs for use in Python.

Each codec has to define four interfaces to make it usable as codec in Python: stateless encoder, stateless decoder, stream reader and stream writer. The stream reader and writers typically reuse the stateless encoder/decoder to implement the file protocols.

The `Codec` class defines the interface for stateless encoders/decoders.

To simplify and standardize error handling, the `encode()` and `decode()` methods may implement different error handling schemes by providing the `errors` string argument. The following string values are defined and implemented by all standard Python codecs:

Value	Meaning
'strict'	Raise <code>UnicodeError</code> (or a subclass); this is the default.
'ignore'	Ignore the character and continue with the next.
'replace'	Replace with a suitable replacement character; Python will use the official U+FFFD REPLACEMENT CHARACTER for the built-in Unicode codecs on decoding and '?' on encoding.
'xmlcharrefreplace'	Replace with the appropriate XML character reference (only for encoding).
'backslashreplace'	Replace with backslashed escape sequences (only for encoding).

The set of allowed values can be extended via `register_error()`.

### Codec Objects

The `Codec` class defines these methods which also define the function interfaces of the stateless encoder and decoder:

`Codec.encode(input[, errors])`

Encodes the object `input` and returns a tuple (output object, length consumed). While codecs are not restricted to use with Unicode, in a Unicode context, encoding converts a Unicode object to a plain string using a particular character set encoding (e.g., `cp1252` or `iso-8859-1`).

`errors` defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the `Codec` instance. Use `StreamCodec` for codecs which have to keep state in order to make encoding/decoding efficient.

The encoder must be able to handle zero length input and return an empty object of the output object type in this situation.

`Codec.decode(input[, errors])`

Decodes the object `input` and returns a tuple (output object, length consumed). In a Unicode context, decoding converts a plain string encoded using a particular character set encoding to a Unicode object.

`input` must be an object which provides the `bf_getreadbuf` buffer slot. Python strings, buffer objects and memory mapped files are examples of objects providing this slot.

`errors` defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the `Codec` instance. Use `StreamCodec` for codecs which have to keep state in order to make encoding/decoding efficient.

The decoder must be able to handle zero length input and return an empty object of the output object type in this situation.

The `IncrementalEncoder` and `IncrementalDecoder` classes provide the basic interface for incremental encoding and decoding. Encoding/decoding the input isn't done with one call to the stateless encoder/decoder function,

but with multiple calls to the `encode()/decode()` method of the incremental encoder/decoder. The incremental encoder/decoder keeps track of the encoding/decoding process during method calls.

The joined output of calls to the `encode()/decode()` method is the same as if all the single inputs were joined into one, and this input was encoded/decoded with the stateless encoder/decoder.

### IncrementalEncoder Objects

New in version 2.5. The `IncrementalEncoder` class is used for encoding an input in multiple steps. It defines the following methods which every incremental encoder must define in order to be compatible with the Python codec registry.

**class** `codecs.IncrementalEncoder` (`[errors]`)

Constructor for an `IncrementalEncoder` instance.

All incremental encoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The `IncrementalEncoder` may implement different error handling schemes by providing the `errors` keyword argument. These parameters are predefined:

- `'strict'` Raise `ValueError` (or a subclass); this is the default.
- `'ignore'` Ignore the character and continue with the next.
- `'replace'` Replace with a suitable replacement character
- `'xmlcharrefreplace'` Replace with the appropriate XML character reference
- `'backslashreplace'` Replace with backslashed escape sequences.

The `errors` argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the `IncrementalEncoder` object.

The set of allowed values for the `errors` argument can be extended with `register_error()`.

**encode** (`object` [`, final`])

Encodes `object` (taking the current state of the encoder into account) and returns the resulting encoded object. If this is the last call to `encode()` `final` must be true (the default is false).

**reset** ()

Reset the encoder to the initial state.

### IncrementalDecoder Objects

The `IncrementalDecoder` class is used for decoding an input in multiple steps. It defines the following methods which every incremental decoder must define in order to be compatible with the Python codec registry.

**class** `codecs.IncrementalDecoder` (`[errors]`)

Constructor for an `IncrementalDecoder` instance.

All incremental decoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The `IncrementalDecoder` may implement different error handling schemes by providing the `errors` keyword argument. These parameters are predefined:

- `'strict'` Raise `ValueError` (or a subclass); this is the default.
- `'ignore'` Ignore the character and continue with the next.

- `'replace'` Replace with a suitable replacement character.

The `errors` argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the `IncrementalDecoder` object.

The set of allowed values for the `errors` argument can be extended with `register_error()`.

**decode** (*object* [, *final* ])

Decodes *object* (taking the current state of the decoder into account) and returns the resulting decoded object. If this is the last call to `decode()` *final* must be true (the default is false). If *final* is true the decoder must decode the input completely and must flush all buffers. If this isn't possible (e.g. because of incomplete byte sequences at the end of the input) it must initiate error handling just like in the stateless case (which might raise an exception).

**reset** ()

Reset the decoder to the initial state.

The `StreamWriter` and `StreamReader` classes provide generic working interfaces which can be used to implement new encoding submodules very easily. See `encodings.utf_8` for an example of how this is done.

### StreamWriter Objects

The `StreamWriter` class is a subclass of `Codec` and defines the following methods which every stream writer must define in order to be compatible with the Python codec registry.

**class** `codecs.StreamWriter` (*stream* [, *errors* ])

Constructor for a `StreamWriter` instance.

All stream writers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

*stream* must be a file-like object open for writing binary data.

The `StreamWriter` may implement different error handling schemes by providing the `errors` keyword argument. These parameters are predefined:

- `'strict'` Raise `ValueError` (or a subclass); this is the default.
- `'ignore'` Ignore the character and continue with the next.
- `'replace'` Replace with a suitable replacement character
- `'xmlcharrefreplace'` Replace with the appropriate XML character reference
- `'backslashreplace'` Replace with backslashed escape sequences.

The `errors` argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the `StreamWriter` object.

The set of allowed values for the `errors` argument can be extended with `register_error()`.

**write** (*object*)

Writes the object's contents encoded to the stream.

**writelines** (*list*)

Writes the concatenated list of strings to the stream (possibly by reusing the `write()` method).

**reset** ()

Flushes and resets the codec buffers used for keeping state.

Calling this method should ensure that the data on the output is put into a clean state that allows appending of new fresh data without having to rescan the whole stream to recover state.

In addition to the above methods, the `StreamWriter` must also inherit all other methods and attributes from the underlying stream.

## StreamReader Objects

The `StreamReader` class is a subclass of `Codec` and defines the following methods which every stream reader must define in order to be compatible with the Python codec registry.

**class** `codecs.StreamReader` (*stream* [, *errors* ])

Constructor for a `StreamReader` instance.

All stream readers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

*stream* must be a file-like object open for reading (binary) data.

The `StreamReader` may implement different error handling schemes by providing the *errors* keyword argument. These parameters are defined:

- 'strict' Raise `ValueError` (or a subclass); this is the default.
- 'ignore' Ignore the character and continue with the next.
- 'replace' Replace with a suitable replacement character.

The *errors* argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the `StreamReader` object.

The set of allowed values for the *errors* argument can be extended with `register_error()`.

**read** ([*size* [, *chars* [, *firstline* ] ] ])

Decodes data from the stream and returns the resulting object.

*chars* indicates the number of characters to read from the stream. `read()` will never return more than *chars* characters, but it might return less, if there are not enough characters available.

*size* indicates the approximate maximum number of bytes to read from the stream for decoding purposes. The decoder can modify this setting as appropriate. The default value -1 indicates to read and decode as much as possible. *size* is intended to prevent having to decode huge files in one step.

*firstline* indicates that it would be sufficient to only return the first line, if there are decoding errors on later lines.

The method should use a greedy read strategy meaning that it should read as much data as is allowed within the definition of the encoding and the given size, e.g. if optional encoding endings or state markers are available on the stream, these should be read too. Changed in version 2.4: *chars* argument added. Changed in version 2.4.2: *firstline* argument added.

**readline** ([*size* [, *keepends* ] ])

Read one line from the input stream and return the decoded data.

*size*, if given, is passed as size argument to the stream's `readline()` method.

If *keepends* is false line-endings will be stripped from the lines returned. Changed in version 2.4: *keepends* argument added.

**readlines** ([*sizehint* [, *keepends* ] ])

Read all lines available on the input stream and return them as a list of lines.

Line-endings are implemented using the codec's decoder method and are included in the list entries if *keepends* is true.

*sizehint*, if given, is passed as the *size* argument to the stream's `read()` method.

**reset ()**

Resets the codec buffers used for keeping state.

Note that no stream repositioning should take place. This method is primarily intended to be able to recover from decoding errors.

In addition to the above methods, the `StreamReader` must also inherit all other methods and attributes from the underlying stream.

The next two base classes are included for convenience. They are not needed by the codec registry, but may provide useful in practice.

### StreamReaderWriter Objects

The `StreamReaderWriter` allows wrapping streams which work in both read and write modes.

The design is such that one can use the factory functions returned by the `lookup ()` function to construct the instance.

**class** `codecs.StreamReaderWriter` (*stream, Reader, Writer, errors*)

Creates a `StreamReaderWriter` instance. *stream* must be a file-like object. *Reader* and *Writer* must be factory functions or classes providing the `StreamReader` and `StreamWriter` interface resp. Error handling is done in the same way as defined for the stream readers and writers.

`StreamReaderWriter` instances define the combined interfaces of `StreamReader` and `StreamWriter` classes. They inherit all other methods and attributes from the underlying stream.

### StreamRecoder Objects

The `StreamRecoder` provide a frontend - backend view of encoding data which is sometimes useful when dealing with different encoding environments.

The design is such that one can use the factory functions returned by the `lookup ()` function to construct the instance.

**class** `codecs.StreamRecoder` (*stream, encode, decode, Reader, Writer, errors*)

Creates a `StreamRecoder` instance which implements a two-way conversion: *encode* and *decode* work on the frontend (the input to `read()` and output of `write()`) while *Reader* and *Writer* work on the backend (reading and writing to the stream).

You can use these objects to do transparent direct recordings from e.g. Latin-1 to UTF-8 and back.

*stream* must be a file-like object.

*encode*, *decode* must adhere to the `Codec` interface. *Reader*, *Writer* must be factory functions or classes providing objects of the `StreamReader` and `StreamWriter` interface respectively.

*encode* and *decode* are needed for the frontend translation, *Reader* and *Writer* for the backend translation. The intermediate format used is determined by the two sets of codecs, e.g. the Unicode codecs will use Unicode as the intermediate encoding.

Error handling is done in the same way as defined for the stream readers and writers.

`StreamRecoder` instances define the combined interfaces of `StreamReader` and `StreamWriter` classes. They inherit all other methods and attributes from the underlying stream.

## 7.8.2 Encodings and Unicode

Unicode strings are stored internally as sequences of codepoints (to be precise as `Py_UNICODE` arrays). Depending on the way Python is compiled (either via `--enable-unicode=ucs2` or `--enable-unicode=ucs4`, with the former being the default) `Py_UNICODE` is either a 16-bit or 32-bit data type. Once a Unicode object is used outside

of CPU and memory, CPU endianness and how these arrays are stored as bytes become an issue. Transforming a unicode object into a sequence of bytes is called encoding and recreating the unicode object from the sequence of bytes is known as decoding. There are many different methods for how this transformation can be done (these methods are also called encodings). The simplest method is to map the codepoints 0-255 to the bytes 0x0-0xff. This means that a unicode object that contains codepoints above U+00FF can't be encoded with this method (which is called 'latin-1' or 'iso-8859-1'). `unicode.encode()` will raise a `UnicodeEncodeError` that looks like this: `UnicodeEncodeError: 'latin-1' codec can't encode character u'\u1234' in position 3: ordinal not in range(256)`.

There's another group of encodings (the so called charmap encodings) that choose a different subset of all unicode code points and how these codepoints are mapped to the bytes 0x0-0xff. To see how this is done simply open e.g. `encodings/cp1252.py` (which is an encoding that is used primarily on Windows). There's a string constant with 256 characters that shows you which character is mapped to which byte value.

All of these encodings can only encode 256 of the 1114112 codepoints defined in unicode. A simple and straightforward way that can store each Unicode code point, is to store each codepoint as four consecutive bytes. There are two possibilities: store the bytes in big endian or in little endian order. These two encodings are called UTF-32-BE and UTF-32-LE respectively. Their disadvantage is that if e.g. you use UTF-32-BE on a little endian machine you will always have to swap bytes on encoding and decoding. UTF-32 avoids this problem: bytes will always be in natural endianness. When these bytes are read by a CPU with a different endianness, then bytes have to be swapped though. To be able to detect the endianness of a UTF-16 or UTF-32 byte sequence, there's the so called BOM ("Byte Order Mark"). This is the Unicode character U+FEFF. This character can be prepended to every UTF-16 or UTF-32 byte sequence. The byte swapped version of this character (0xFFFE) is an illegal character that may not appear in a Unicode text. So when the first character in an UTF-16 or UTF-32 byte sequence appears to be a U+FFFE the bytes have to be swapped on decoding. Unfortunately the character U+FEFF had a second purpose as a ZERO WIDTH NO-BREAK SPACE: a character that has no width and doesn't allow a word to be split. It can e.g. be used to give hints to a ligature algorithm. With Unicode 4.0 using U+FEFF as a ZERO WIDTH NO-BREAK SPACE has been deprecated (with U+2060 (WORD JOINER) assuming this role). Nevertheless Unicode software still must be able to handle U+FEFF in both roles: as a BOM it's a device to determine the storage layout of the encoded bytes, and vanishes once the byte sequence has been decoded into a Unicode string; as a ZERO WIDTH NO-BREAK SPACE it's a normal character that will be decoded like any other.

There's another encoding that is able to encoding the full range of Unicode characters: UTF-8. UTF-8 is an 8-bit encoding, which means there are no issues with byte order in UTF-8. Each byte in a UTF-8 byte sequence consists of two parts: marker bits (the most significant bits) and payload bits. The marker bits are a sequence of zero to four 1 bits followed by a 0 bit. Unicode characters are encoded like this (with x being payload bits, which when concatenated give the Unicode character):

Range	Encoding
U-00000000 ... U-0000007F	0xxxxxxx
U-00000080 ... U-000007FF	110xxxxx 10xxxxxx
U-00000800 ... U-0000FFFF	1110xxxx 10xxxxxx 10xxxxxx
U-00010000 ... U-0010FFFF	11110xxx 10xxxxxx 10xxxxxx 10xxxxxx

The least significant bit of the Unicode character is the rightmost x bit.

As UTF-8 is an 8-bit encoding no BOM is required and any U+FEFF character in the decoded Unicode string (even if it's the first character) is treated as a ZERO WIDTH NO-BREAK SPACE.

Without external information it's impossible to reliably determine which encoding was used for encoding a Unicode string. Each charmap encoding can decode any random byte sequence. However that's not possible with UTF-8, as UTF-8 byte sequences have a structure that doesn't allow arbitrary byte sequences. To increase the reliability with which a UTF-8 encoding can be detected, Microsoft invented a variant of UTF-8 (that Python 2.5 calls "utf-8-sig") for its Notepad program: Before any of the Unicode characters is written to the file, a UTF-8 encoded BOM (which looks like this as a byte sequence: 0xef, 0xbb, 0xbf) is written. As it's rather improbable that any charmap encoded file starts with these byte values (which would e.g. map to

LATIN SMALL LETTER I WITH DIAERESIS

RIGHT-POINTING DOUBLE ANGLE QUOTATION MARK  
 INVERTED QUESTION MARK

in iso-8859-1), this increases the probability that a `utf-8-sig` encoding can be correctly guessed from the byte sequence. So here the BOM is not used to be able to determine the byte order used for generating the byte sequence, but as a signature that helps in guessing the encoding. On encoding the `utf-8-sig` codec will write `0xef, 0xbb, 0xbf` as the first three bytes to the file. On decoding `utf-8-sig` will skip those three bytes if they appear as the first three bytes in the file. In UTF-8, the use of the BOM is discouraged and should generally be avoided.

### 7.8.3 Standard Encodings

Python comes with a number of codecs built-in, either implemented as C functions or with dictionaries as mapping tables. The following table lists the codecs by name, together with a few common aliases, and the languages for which the encoding is likely used. Neither the list of aliases nor the list of languages is meant to be exhaustive. Notice that spelling alternatives that only differ in case or use a hyphen instead of an underscore are also valid aliases; therefore, e.g. `'utf-8'` is a valid alias for the `'utf_8'` codec.

Many of the character sets support the same languages. They vary in individual characters (e.g. whether the EURO SIGN is supported or not), and in the assignment of characters to code positions. For the European languages in particular, the following variants typically exist:

- an ISO 8859 codeset
- a Microsoft Windows code page, which is typically derived from a 8859 codeset, but replaces control characters with additional graphic characters
- an IBM EBCDIC code page
- an IBM PC code page, which is ASCII compatible

Codec	Aliases	Languages
<code>ascii</code>	646, us-ascii	English
<code>big5</code>	<code>big5-tw</code> , <code>csbig5</code>	Traditional Chinese
<code>big5hkscs</code>	<code>big5-hkscs</code> , <code>hkscs</code>	Traditional Chinese
<code>cp037</code>	IBM037, IBM039	English
<code>cp424</code>	EBCDIC-CP-HE, IBM424	Hebrew
<code>cp437</code>	437, IBM437	English
<code>cp500</code>	EBCDIC-CP-BE, EBCDIC-CP-CH, IBM500	Western European
<code>cp720</code>		Arabic
<code>cp737</code>		Greek
<code>cp775</code>	IBM775	Baltic languages
<code>cp850</code>	850, IBM850	Western European
<code>cp852</code>	852, IBM852	Central and Eastern European
<code>cp855</code>	855, IBM855	Bulgarian, Byelorussian
<code>cp856</code>		Hebrew
<code>cp857</code>	857, IBM857	Turkish
<code>cp858</code>	858, IBM858	Western European
<code>cp860</code>	860, IBM860	Portuguese
<code>cp861</code>	861, CP-IS, IBM861	Icelandic
<code>cp862</code>	862, IBM862	Hebrew
<code>cp863</code>	863, IBM863	Canadian
<code>cp864</code>	IBM864	Arabic
<code>cp865</code>	865, IBM865	Danish, Norwegian
<code>cp866</code>	866, IBM866	Russian
<code>cp869</code>	869, CP-GR, IBM869	Greek

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cp874		Thai
cp875		Greek
cp932	932, ms932, mskanji, ms-kanji	Japanese
cp949	949, ms949, uhc	Korean
cp950	950, ms950	Traditional Chinese
cp1006		Urdu
cp1026	ibm1026	Turkish
cp1140	ibm1140	Western European
cp1250	windows-1250	Central and Eastern European
cp1251	windows-1251	Bulgarian, Byelorussian
cp1252	windows-1252	Western European
cp1253	windows-1253	Greek
cp1254	windows-1254	Turkish
cp1255	windows-1255	Hebrew
cp1256	windows-1256	Arabic
cp1257	windows-1257	Baltic languages
cp1258	windows-1258	Vietnamese
euc_jp	eucjp, ujis, u-jis	Japanese
euc_jis_2004	jisx0213, eucjis2004	Japanese
euc_jisx0213	eucjisx0213	Japanese
euc_kr	euckr, korean, ksc5601, ks_c-5601, ks_c-5601-1987, ksx1001, ks_x-1001	Korean
gb2312	chinese, csiso58gb231280, euc-cn, euccn, eucgb2312-cn, gb2312-1980, gb2312-80, iso-ir-58	Simplified Chinese
gbk	936, cp936, ms936	Unified Chinese
gb18030	gb18030-2000	Unified Chinese
hz	hzgb, hz-gb, hz-gb-2312	Simplified Chinese
iso2022_jp	csiso2022jp, iso2022jp, iso-2022-jp	Japanese
iso2022_jp_1	iso2022jp-1, iso-2022-jp-1	Japanese
iso2022_jp_2	iso2022jp-2, iso-2022-jp-2	Japanese, Korean
iso2022_jp_2004	iso2022jp-2004, iso-2022-jp-2004	Japanese
iso2022_jp_3	iso2022jp-3, iso-2022-jp-3	Japanese
iso2022_jp_ext	iso2022jp-ext, iso-2022-jp-ext	Japanese
iso2022_kr	csiso2022kr, iso2022kr, iso-2022-kr	Korean
latin_1	iso-8859-1, iso8859-1, 8859, cp819, latin, latin1, L1	West European
iso8859_2	iso-8859-2, latin2, L2	Central and Eastern European
iso8859_3	iso-8859-3, latin3, L3	Esperanto, Maltese
iso8859_4	iso-8859-4, latin4, L4	Baltic languages
iso8859_5	iso-8859-5, cyrillic	Bulgarian, Byelorussian
iso8859_6	iso-8859-6, arabic	Arabic
iso8859_7	iso-8859-7, greek, greek8	Greek
iso8859_8	iso-8859-8, hebrew	Hebrew
iso8859_9	iso-8859-9, latin5, L5	Turkish
iso8859_10	iso-8859-10, latin6, L6	Nordic languages
iso8859_13	iso-8859-13, latin7, L7	Baltic languages
iso8859_14	iso-8859-14, latin8, L8	Celtic languages
iso8859_15	iso-8859-15, latin9, L9	Western European
iso8859_16	iso-8859-16, latin10, L10	South-Eastern European
johab	cp1361, ms1361	Korean
koi8_r		Russian
koi8_u		Ukrainian
mac_cyrillic	maccyrillic	Bulgarian, Byelorussian
mac_greek	macgreek	Greek
mac_iceland	maciceland	Icelandic

Table 7.1 – continued from previous page

mac_latin2	maclatin2, maccentraleurope	Central and East
mac_roman	macroman	Western Europe
mac_turkish	macturkish	Turkish
ptcp154	csptcp154, pt154, cp154, cyrillic-asian	Kazakh
shift_jis	csshiftjis, shiftjis, sjis, s_jis	Japanese
shift_jis_2004	shiftjis2004, sjis_2004, sjis2004	Japanese
shift_jisx0213	shiftjisx0213, sjisx0213, s_jisx0213	Japanese
utf_32	U32, utf32	all languages
utf_32_be	UTF-32BE	all languages
utf_32_le	UTF-32LE	all languages
utf_16	U16, utf16	all languages
utf_16_be	UTF-16BE	all languages (B
utf_16_le	UTF-16LE	all languages (B
utf_7	U7, unicode-1-1-utf-7	all languages
utf_8	U8, UTF, utf8	all languages
utf_8_sig		all languages

A number of codecs are specific to Python, so their codec names have no meaning outside Python. Some of them don't convert from Unicode strings to byte strings, but instead use the property of the Python codecs machinery that any bijective function with one argument can be considered as an encoding.

For the codecs listed below, the result in the “encoding” direction is always a byte string. The result of the “decoding” direction is listed as operand type in the table.

Codec	Aliases	Operand type	Purpose
base64_codec	base64, base-64	byte string	Convert operand to MIME base64
bz2_codec	bz2	byte string	Compress the operand using bz2
hex_codec	hex	byte string	Convert operand to hexadecimal representation, with two digits per byte
idna		Uni- code string	Implements <b>RFC 3490</b> , see also <code>encodings.idna</code>
mbcs	dbcs	Uni- code string	Windows only: Encode operand according to the ANSI codepage (CP_ACP)
palmos		Uni- code string	Encoding of PalmOS 3.5
punycode		Uni- code string	Implements <b>RFC 3492</b>
quo- pri_codec	quopri, quoted-printable, quotedprintable	byte string	Convert operand to MIME quoted printable
raw_unicode_escape		Uni- code string	Produce a string that is suitable as raw Unicode literal in Python source code
rot_13	rot13	Uni- code string	Returns the Caesar-cypher encryption of the operand
string_escape		byte string	Produce a string that is suitable as string literal in Python source code
unde- fined		any	Raise an exception for all conversions. Can be used as the system encoding if no automatic <i>coercion</i> between byte and Unicode strings is desired.
uni- code_escape		Uni- code string	Produce a string that is suitable as Unicode literal in Python source code
uni- code_internal		Uni- code string	Return the internal representation of the operand
uu_codec	uu	byte string	Convert the operand using uuencode
zlib_codec	zip, zlib	byte string	Compress the operand using gzip

New in version 2.3: The `idna` and `punycode` encodings.

## 7.8.4 `encodings.idna` — Internationalized Domain Names in Applications

New in version 2.3. This module implements **RFC 3490** (Internationalized Domain Names in Applications) and **RFC 3492** (Nameprep: A Stringprep Profile for Internationalized Domain Names (IDN)). It builds upon the `punycode` encoding and `stringprep`.

These RFCs together define a protocol to support non-ASCII characters in domain names. A domain name containing

non-ASCII characters (such as `www.Alliancefrançaise.nu`) is converted into an ASCII-compatible encoding (ACE, such as `www.xn--alliancefranaise-npb.nu`). The ACE form of the domain name is then used in all places where arbitrary characters are not allowed by the protocol, such as DNS queries, HTTP `Host` fields, and so on. This conversion is carried out in the application; if possible invisible to the user: The application should transparently convert Unicode domain labels to IDNA on the wire, and convert back ACE labels to Unicode before presenting them to the user.

Python supports this conversion in several ways: the `idna` codec performs conversion between Unicode and ACE, separating an input string into labels based on the separator characters defined in section 3.1 (1) of RFC 3490 and converting each label to ACE as required, and conversely separating an input byte string into labels based on the `.` separator and converting any ACE labels found into unicode. Furthermore, the `socket` module transparently converts Unicode host names to ACE, so that applications need not be concerned about converting host names themselves when they pass them to the `socket` module. On top of that, modules that have host names as function parameters, such as `httplib` and `ftplib`, accept Unicode host names (`httplib` then also transparently sends an IDNA hostname in the `Host` field if it sends that field at all).

When receiving host names from the wire (such as in reverse name lookup), no automatic conversion to Unicode is performed: Applications wishing to present such host names to the user should decode them to Unicode.

The module `encodings.idna` also implements the nameprep procedure, which performs certain normalizations on host names, to achieve case-insensitivity of international domain names, and to unify similar characters. The nameprep functions can be used directly if desired.

`encodings.idna.nameprep` (*label*)

Return the nameprepped version of *label*. The implementation currently assumes query strings, so `AllowUnassigned` is true.

`encodings.idna.ToASCII` (*label*)

Convert a label to ASCII, as specified in RFC 3490. `UseSTD3ASCIIRules` is assumed to be false.

`encodings.idna.ToUnicode` (*label*)

Convert a label to Unicode, as specified in RFC 3490.

### 7.8.5 `encodings.utf_8_sig` — UTF-8 codec with BOM signature

New in version 2.5. This module implements a variant of the UTF-8 codec: On encoding a UTF-8 encoded BOM will be prepended to the UTF-8 encoded bytes. For the stateful encoder this is only done once (on the first write to the byte stream). For decoding an optional UTF-8 encoded BOM at the start of the data will be skipped.

## 7.9 `unicodedata` — Unicode Database

This module provides access to the Unicode Character Database which defines character properties for all Unicode characters. The data in this database is based on the `UnicodeData.txt` file version 5.2.0 which is publicly available from <ftp://ftp.unicode.org/>.

The module uses the same names and symbols as defined by the UnicodeData File Format 5.2.0 (see <http://www.unicode.org/reports/tr44/tr44-4.html>). It defines the following functions:

`unicodedata.lookup` (*name*)

Look up character by name. If a character with the given name is found, return the corresponding Unicode character. If not found, `KeyError` is raised.

`unicodedata.name` (*unichr*[, *default* ])

Returns the name assigned to the Unicode character *unichr* as a string. If no name is defined, *default* is returned, or, if not given, `ValueError` is raised.

`unicodedata.decimal(unichr[, default])`

Returns the decimal value assigned to the Unicode character *unichr* as integer. If no such value is defined, *default* is returned, or, if not given, `ValueError` is raised.

`unicodedata.digit(unichr[, default])`

Returns the digit value assigned to the Unicode character *unichr* as integer. If no such value is defined, *default* is returned, or, if not given, `ValueError` is raised.

`unicodedata.numeric(unichr[, default])`

Returns the numeric value assigned to the Unicode character *unichr* as float. If no such value is defined, *default* is returned, or, if not given, `ValueError` is raised.

`unicodedata.category(unichr)`

Returns the general category assigned to the Unicode character *unichr* as string.

`unicodedata.bidirectional(unichr)`

Returns the bidirectional category assigned to the Unicode character *unichr* as string. If no such value is defined, an empty string is returned.

`unicodedata.combining(unichr)`

Returns the canonical combining class assigned to the Unicode character *unichr* as integer. Returns 0 if no combining class is defined.

`unicodedata.east_asian_width(unichr)`

Returns the east asian width assigned to the Unicode character *unichr* as string. New in version 2.4.

`unicodedata.mirrored(unichr)`

Returns the mirrored property assigned to the Unicode character *unichr* as integer. Returns 1 if the character has been identified as a “mirrored” character in bidirectional text, 0 otherwise.

`unicodedata.decomposition(unichr)`

Returns the character decomposition mapping assigned to the Unicode character *unichr* as string. An empty string is returned in case no such mapping is defined.

`unicodedata.normalize(form, unistr)`

Return the normal form *form* for the Unicode string *unistr*. Valid values for *form* are ‘NFC’, ‘NFKC’, ‘NFD’, and ‘NFKD’.

The Unicode standard defines various normalization forms of a Unicode string, based on the definition of canonical equivalence and compatibility equivalence. In Unicode, several characters can be expressed in various way. For example, the character U+00C7 (LATIN CAPITAL LETTER C WITH CEDILLA) can also be expressed as the sequence U+0043 (LATIN CAPITAL LETTER C) U+0327 (COMBINING CEDILLA).

For each character, there are two normal forms: normal form C and normal form D. Normal form D (NFD) is also known as canonical decomposition, and translates each character into its decomposed form. Normal form C (NFC) first applies a canonical decomposition, then composes pre-combined characters again.

In addition to these two forms, there are two additional normal forms based on compatibility equivalence. In Unicode, certain characters are supported which normally would be unified with other characters. For example, U+2160 (ROMAN NUMERAL ONE) is really the same thing as U+0049 (LATIN CAPITAL LETTER I). However, it is supported in Unicode for compatibility with existing character sets (e.g. gb2312).

The normal form KD (NFKD) will apply the compatibility decomposition, i.e. replace all compatibility characters with their equivalents. The normal form KC (NFKC) first applies the compatibility decomposition, followed by the canonical composition.

Even if two unicode strings are normalized and look the same to a human reader, if one has combining characters and the other doesn’t, they may not compare equal. New in version 2.3.

In addition, the module exposes the following constant:

### `unicodedata.unicdata_version`

The version of the Unicode database used in this module. New in version 2.3.

### `unicodedata.ucd_3_2_0`

This is an object that has the same methods as the entire module, but uses the Unicode database version 3.2 instead, for applications that require this specific version of the Unicode database (such as IDNA). New in version 2.5.

Examples:

```
>>> import unicodedata
>>> unicodedata.lookup('LEFT CURLY BRACKET')
u'{'
>>> unicodedata.name(u'/')
'SOLIDUS'
>>> unicodedata.decimal(u'9')
9
>>> unicodedata.decimal(u'a')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: not a decimal
>>> unicodedata.category(u'A') # 'L'etter, 'u'ppercase
'Lu'
>>> unicodedata.bidirectional(u'\u0660') # 'A'rabic, 'N'umber
'AN'
```

## 7.10 stringprep — Internet String Preparation

New in version 2.3. When identifying things (such as host names) in the internet, it is often necessary to compare such identifications for “equality”. Exactly how this comparison is executed may depend on the application domain, e.g. whether it should be case-insensitive or not. It may be also necessary to restrict the possible identifications, to allow only identifications consisting of “printable” characters.

**RFC 3454** defines a procedure for “preparing” Unicode strings in internet protocols. Before passing strings onto the wire, they are processed with the preparation procedure, after which they have a certain normalized form. The RFC defines a set of tables, which can be combined into profiles. Each profile must define which tables it uses, and what other optional parts of the `stringprep` procedure are part of the profile. One example of a `stringprep` profile is `nameprep`, which is used for internationalized domain names.

The module `stringprep` only exposes the tables from RFC 3454. As these tables would be very large to represent them as dictionaries or lists, the module uses the Unicode character database internally. The module source code itself was generated using the `mkstringprep.py` utility.

As a result, these tables are exposed as functions, not as data structures. There are two kinds of tables in the RFC: sets and mappings. For a set, `stringprep` provides the “characteristic function”, i.e. a function that returns true if the parameter is part of the set. For mappings, it provides the mapping function: given the key, it returns the associated value. Below is a list of all functions available in the module.

`stringprep.in_table_a1` (*code*)

Determine whether *code* is in tableA.1 (Unassigned code points in Unicode 3.2).

`stringprep.in_table_b1` (*code*)

Determine whether *code* is in tableB.1 (Commonly mapped to nothing).

`stringprep.map_table_b2` (*code*)

Return the mapped value for *code* according to tableB.2 (Mapping for case-folding used with NFKC).

`stringprep.map_table_b3` (*code*)  
Return the mapped value for *code* according to tableB.3 (Mapping for case-folding used with no normalization).

`stringprep.in_table_c11` (*code*)  
Determine whether *code* is in tableC.1.1 (ASCII space characters).

`stringprep.in_table_c12` (*code*)  
Determine whether *code* is in tableC.1.2 (Non-ASCII space characters).

`stringprep.in_table_c11_c12` (*code*)  
Determine whether *code* is in tableC.1 (Space characters, union of C.1.1 and C.1.2).

`stringprep.in_table_c21` (*code*)  
Determine whether *code* is in tableC.2.1 (ASCII control characters).

`stringprep.in_table_c22` (*code*)  
Determine whether *code* is in tableC.2.2 (Non-ASCII control characters).

`stringprep.in_table_c21_c22` (*code*)  
Determine whether *code* is in tableC.2 (Control characters, union of C.2.1 and C.2.2).

`stringprep.in_table_c3` (*code*)  
Determine whether *code* is in tableC.3 (Private use).

`stringprep.in_table_c4` (*code*)  
Determine whether *code* is in tableC.4 (Non-character code points).

`stringprep.in_table_c5` (*code*)  
Determine whether *code* is in tableC.5 (Surrogate codes).

`stringprep.in_table_c6` (*code*)  
Determine whether *code* is in tableC.6 (Inappropriate for plain text).

`stringprep.in_table_c7` (*code*)  
Determine whether *code* is in tableC.7 (Inappropriate for canonical representation).

`stringprep.in_table_c8` (*code*)  
Determine whether *code* is in tableC.8 (Change display properties or are deprecated).

`stringprep.in_table_c9` (*code*)  
Determine whether *code* is in tableC.9 (Tagging characters).

`stringprep.in_table_d1` (*code*)  
Determine whether *code* is in tableD.1 (Characters with bidirectional property “R” or “AL”).

`stringprep.in_table_d2` (*code*)  
Determine whether *code* is in tableD.2 (Characters with bidirectional property “L”).

## 7.11 `fpformat` — Floating point conversions

Deprecated since version 2.6: The `fpformat` module has been removed in Python 3. The `fpformat` module defines functions for dealing with floating point numbers representations in 100% pure Python.

---

**Note:** This module is unnecessary: everything here can be done using the `%` string interpolation operator described in the *String Formatting Operations* section.

---

The `fpformat` module defines the following functions and an exception:

`fpformat.fix(x, digs)`

Format  $x$  as `[-]ddd.ddd` with  $digs$  digits after the point and at least one digit before. If  $digs \leq 0$ , the decimal point is suppressed.

$x$  can be either a number or a string that looks like one.  $digs$  is an integer.

Return value is a string.

`fpformat.sci(x, digs)`

Format  $x$  as `[-]d.dddE[+-]ddd` with  $digs$  digits after the point and exactly one digit before. If  $digs \leq 0$ , one digit is kept and the point is suppressed.

$x$  can be either a real number, or a string that looks like one.  $digs$  is an integer.

Return value is a string.

**exception** `fpformat.NotANumber`

Exception raised when a string passed to `fix()` or `sci()` as the  $x$  parameter does not look like a number. This is a subclass of `ValueError` when the standard exceptions are strings. The exception value is the improperly formatted string that caused the exception to be raised.

Example:

```
>>> import fpformat
>>> fpformat.fix(1.23, 1)
'1.2'
```

# DATA TYPES

The modules described in this chapter provide a variety of specialized data types such as dates and times, fixed-type arrays, heap queues, synchronized queues, and sets.

Python also provides some built-in data types, in particular, `dict`, `list`, `set` (which along with `frozenset`, replaces the deprecated `sets` module), and `tuple`. The `str` class can be used to handle binary data and 8-bit text, and the `unicode` class to handle Unicode text.

The following modules are documented in this chapter:

## 8.1 `datetime` — Basic date and time types

New in version 2.3. The `datetime` module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient attribute extraction for output formatting and manipulation. For related functionality, see also the `time` and `calendar` modules.

There are two kinds of date and time objects: “naive” and “aware”.

An aware object has sufficient knowledge of applicable algorithmic and political time adjustments, such as time zone and daylight saving time information, to locate itself relative to other aware objects. An aware object is used to represent a specific moment in time that is not open to interpretation <sup>1</sup>.

A naive object does not contain enough information to unambiguously locate itself relative to other date/time objects. Whether a naive object represents Coordinated Universal Time (UTC), local time, or time in some other timezone is purely up to the program, just like it’s up to the program whether a particular number represents metres, miles, or mass. Naive objects are easy to understand and to work with, at the cost of ignoring some aspects of reality.

For applications requiring aware objects, `datetime` and `time` objects have an optional time zone information attribute, `tzinfo`, that can be set to an instance of a subclass of the abstract `tzinfo` class. These `tzinfo` objects capture information about the offset from UTC time, the time zone name, and whether Daylight Saving Time is in effect. Note that no concrete `tzinfo` classes are supplied by the `datetime` module. Supporting timezones at whatever level of detail is required is up to the application. The rules for time adjustment across the world are more political than rational, and there is no standard suitable for every application.

The `datetime` module exports the following constants:

`datetime`.**MINYEAR**

The smallest year number allowed in a `date` or `datetime` object. `MINYEAR` is 1.

`datetime`.**MAXYEAR**

The largest year number allowed in a `date` or `datetime` object. `MAXYEAR` is 9999.

---

<sup>1</sup> If, that is, we ignore the effects of Relativity

**See Also:**

**Module `calendar`** General calendar related functions.

**Module `time`** Time access and conversions.

### 8.1.1 Available Types

**class `datetime.date`**

An idealized naive date, assuming the current Gregorian calendar always was, and always will be, in effect. Attributes: `year`, `month`, and `day`.

**class `datetime.time`**

An idealized time, independent of any particular day, assuming that every day has exactly 24\*60\*60 seconds (there is no notion of “leap seconds” here). Attributes: `hour`, `minute`, `second`, `microsecond`, and `tzinfo`.

**class `datetime.datetime`**

A combination of a date and a time. Attributes: `year`, `month`, `day`, `hour`, `minute`, `second`, `microsecond`, and `tzinfo`.

**class `datetime.timedelta`**

A duration expressing the difference between two `date`, `time`, or `datetime` instances to microsecond resolution.

**class `datetime.tzinfo`**

An abstract base class for time zone information objects. These are used by the `datetime` and `time` classes to provide a customizable notion of time adjustment (for example, to account for time zone and/or daylight saving time).

Objects of these types are immutable.

Objects of the `date` type are always naive.

An object of type `time` or `datetime` may be naive or aware. A `datetime` object *d* is aware if `d.tzinfo` is not `None` and `d.tzinfo.utcoffset(d)` does not return `None`. If `d.tzinfo` is `None`, or if `d.tzinfo` is not `None` but `d.tzinfo.utcoffset(d)` returns `None`, *d* is naive. A `time` object *t* is aware if `t.tzinfo` is not `None` and `t.tzinfo.utcoffset(None)` does not return `None`. Otherwise, *t* is naive.

The distinction between naive and aware doesn’t apply to `timedelta` objects.

Subclass relationships:

```
object
  timedelta
  tzinfo
  time
  date
    datetime
```

### 8.1.2 `timedelta` Objects

A `timedelta` object represents a duration, the difference between two dates or times.

**class `datetime.timedelta`** (`days` [, `seconds` [, `microseconds` [, `milliseconds` [, `minutes` [, `hours` [, `weeks` ]]]]])

All arguments are optional and default to 0. Arguments may be ints, longs, or floats, and may be positive or negative.

Only *days*, *seconds* and *microseconds* are stored internally. Arguments are converted to those units:

- A millisecond is converted to 1000 microseconds.
- A minute is converted to 60 seconds.
- An hour is converted to 3600 seconds.
- A week is converted to 7 days.

and *days*, *seconds* and *microseconds* are then normalized so that the representation is unique, with

- $0 \leq \text{microseconds} < 1000000$
- $0 \leq \text{seconds} < 3600 * 24$  (the number of seconds in one day)
- $-999999999 \leq \text{days} \leq 999999999$

If any argument is a float and there are fractional microseconds, the fractional microseconds left over from all arguments are combined and their sum is rounded to the nearest microsecond. If no argument is a float, the conversion and normalization processes are exact (no information is lost).

If the normalized value of *days* lies outside the indicated range, `OverflowError` is raised.

Note that normalization of negative values may be surprising at first. For example,

```
>>> from datetime import timedelta
>>> d = timedelta(microseconds=-1)
>>> (d.days, d.seconds, d.microseconds)
(-1, 86399, 999999)
```

Class attributes are:

`timedelta.min`

The most negative `timedelta` object, `timedelta(-999999999)`.

`timedelta.max`

The most positive `timedelta` object, `timedelta(days=999999999, hours=23, minutes=59, seconds=59, microseconds=999999)`.

`timedelta.resolution`

The smallest possible difference between non-equal `timedelta` objects, `timedelta(microseconds=1)`.

Note that, because of normalization, `timedelta.max > -timedelta.min`. `-timedelta.max` is not representable as a `timedelta` object.

Instance attributes (read-only):

Attribute	Value
<code>days</code>	Between -999999999 and 999999999 inclusive
<code>seconds</code>	Between 0 and 86399 inclusive
<code>microseconds</code>	Between 0 and 999999 inclusive

Supported operations:

Operation	Result
<code>t1 = t2 + t3</code>	Sum of <i>t2</i> and <i>t3</i> . Afterwards <code>t1-t2 == t3</code> and <code>t1-t3 == t2</code> are true. (1)
<code>t1 = t2 - t3</code>	Difference of <i>t2</i> and <i>t3</i> . Afterwards <code>t1 == t2 - t3</code> and <code>t2 == t1 + t3</code> are true. (1)
<code>t1 = t2 * i</code> or <code>t1 = i * t2</code>	Delta multiplied by an integer or long. Afterwards <code>t1 // i == t2</code> is true, provided <code>i != 0</code> . In general, <code>t1 * i == t1 * (i-1) + t1</code> is true. (1)
<code>t1 = t2 // i</code>	The floor is computed and the remainder (if any) is thrown away. (3)
<code>+t1</code>	Returns a <code>timedelta</code> object with the same value. (2)
<code>-t1</code>	equivalent to <code>timedelta(-t1.days, -t1.seconds, -t1.microseconds)</code> , and to <code>t1* -1</code> . (1)(4)
<code>abs(t)</code>	equivalent to <code>+t</code> when <code>t.days &gt;= 0</code> , and to <code>-t</code> when <code>t.days &lt; 0</code> . (2)
<code>str(t)</code>	Returns a string in the form <code>[D day[s], ][H]H:MM:SS[.UUUUUU]</code> , where <code>D</code> is negative for negative <code>t</code> . (5)
<code>repr(t)</code>	Returns a string in the form <code>datetime.timedelta(D[, S[, U]])</code> , where <code>D</code> is negative for negative <code>t</code> . (5)

Notes:

1. This is exact, but may overflow.
2. This is exact, and cannot overflow.
3. Division by 0 raises `ZeroDivisionError`.
4. `-timedelta.max` is not representable as a `timedelta` object.
5. String representations of `timedelta` objects are normalized similarly to their internal representation. This leads to somewhat unusual results for negative `timedeltas`. For example:

```
>>> timedelta(hours=-5)
datetime.timedelta(-1, 68400)
>>> print(_)
-1 day, 19:00:00
```

In addition to the operations listed above `timedelta` objects support certain additions and subtractions with `date` and `datetime` objects (see below).

Comparisons of `timedelta` objects are supported with the `timedelta` object representing the smaller duration considered to be the smaller `timedelta`. In order to stop mixed-type comparisons from falling back to the default comparison by object address, when a `timedelta` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.

`timedelta` objects are *hashable* (usable as dictionary keys), support efficient pickling, and in Boolean contexts, a `timedelta` object is considered to be true if and only if it isn't equal to `timedelta(0)`.

Instance methods:

`timedelta.total_seconds()`

Return the total number of seconds contained in the duration. Equivalent to `(td.microseconds + (td.seconds + td.days * 24 * 3600) * 10**6) / 10**6` computed with true division enabled.

Note that for very large time intervals (greater than 270 years on most platforms) this method will lose microsecond accuracy. New in version 2.7.

Example usage:

```
>>> from datetime import timedelta
>>> year = timedelta(days=365)
>>> another_year = timedelta(weeks=40, days=84, hours=23,
...                          minutes=50, seconds=600) # adds up to 365 days
```

```

>>> year.total_seconds()
31536000.0
>>> year == another_year
True
>>> ten_years = 10 * year
>>> ten_years, ten_years.days // 365
(datetime.timedelta(3650), 10)
>>> nine_years = ten_years - year
>>> nine_years, nine_years.days // 365
(datetime.timedelta(3285), 9)
>>> three_years = nine_years // 3;
>>> three_years, three_years.days // 365
(datetime.timedelta(1095), 3)
>>> abs(three_years - ten_years) == 2 * three_years + year
True

```

### 8.1.3 date Objects

A `date` object represents a date (year, month and day) in an idealized calendar, the current Gregorian calendar indefinitely extended in both directions. January 1 of year 1 is called day number 1, January 2 of year 1 is called day number 2, and so on. This matches the definition of the “proleptic Gregorian” calendar in Dershowitz and Reingold’s book *Calendrical Calculations*, where it’s the base calendar for all computations. See the book for algorithms for converting between proleptic Gregorian ordinals and many other calendar systems.

**class** `datetime.date` (*year, month, day*)

All arguments are required. Arguments may be ints or longs, in the following ranges:

- `MINYEAR <= year <= MAXYEAR`
- `1 <= month <= 12`
- `1 <= day <= number of days in the given month and year`

If an argument outside those ranges is given, `ValueError` is raised.

Other constructors, all class methods:

**classmethod** `date.today()`

Return the current local date. This is equivalent to `date.fromtimestamp(time.time())`.

**classmethod** `date.fromtimestamp(timestamp)`

Return the local date corresponding to the POSIX timestamp, such as is returned by `time.time()`. This may raise `ValueError`, if the timestamp is out of the range of values supported by the platform `C localtime()` function. It’s common for this to be restricted to years from 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by `fromtimestamp()`.

**classmethod** `date.fromordinal(ordinal)`

Return the date corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. `ValueError` is raised unless `1 <= ordinal <= date.max.toordinal()`. For any date `d`, `date.fromordinal(d.toordinal()) == d`.

Class attributes:

`date.min`

The earliest representable date, `date(MINYEAR, 1, 1)`.

`date.max`

The latest representable date, `date(MAXYEAR, 12, 31)`.

`date.resolution`

The smallest possible difference between non-equal date objects, `timedelta(days=1)`.

Instance attributes (read-only):

`date.year`

Between `MINYEAR` and `MAXYEAR` inclusive.

`date.month`

Between 1 and 12 inclusive.

`date.day`

Between 1 and the number of days in the given month of the given year.

Supported operations:

Operation	Result
<code>date2 = date1 + timedelta</code>	<code>date2</code> is <code>timedelta.days</code> days removed from <code>date1</code> . (1)
<code>date2 = date1 - timedelta</code>	Computes <code>date2</code> such that <code>date2 + timedelta == date1</code> . (2)
<code>timedelta = date1 - date2</code>	(3)
<code>date1 &lt; date2</code>	<code>date1</code> is considered less than <code>date2</code> when <code>date1</code> precedes <code>date2</code> in time. (4)

Notes:

1. `date2` is moved forward in time if `timedelta.days > 0`, or backward if `timedelta.days < 0`. Afterward `date2 - date1 == timedelta.days`. `timedelta.seconds` and `timedelta.microseconds` are ignored. `OverflowError` is raised if `date2.year` would be smaller than `MINYEAR` or larger than `MAXYEAR`.
2. This isn't quite equivalent to `date1 + (-timedelta)`, because `-timedelta` in isolation can overflow in cases where `date1 - timedelta` does not. `timedelta.seconds` and `timedelta.microseconds` are ignored.
3. This is exact, and cannot overflow. `timedelta.seconds` and `timedelta.microseconds` are 0, and `date2 + timedelta == date1` after.
4. In other words, `date1 < date2` if and only if `date1.toordinal() < date2.toordinal()`. In order to stop comparison from falling back to the default scheme of comparing object addresses, date comparison normally raises `TypeError` if the other comparand isn't also a `date` object. However, `NotImplemented` is returned instead if the other comparand has a `timetuple()` attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a `date` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.

Dates can be used as dictionary keys. In Boolean contexts, all `date` objects are considered to be true.

Instance methods:

`date.replace(year, month, day)`

Return a date with the same value, except for those parameters given new values by whichever keyword arguments are specified. For example, if `d == date(2002, 12, 31)`, then `d.replace(day=26) == date(2002, 12, 26)`.

`date.timetuple()`

Return a `time.struct_time` such as returned by `time.localtime()`. The hours, minutes and seconds are 0, and the DST flag is -1. `d.timetuple()` is equivalent to `time.struct_time((d.year, d.month, d.day, 0, 0, 0, d.weekday(), yday, -1))`, where `yday = d.toordinal() - date(d.year, 1, 1).toordinal() + 1` is the day number within the current year starting with 1 for January 1st.

`date.toordinal()`

Return the proleptic Gregorian ordinal of the date, where January 1 of year 1 has ordinal 1. For any `date` object `d`, `date.fromordinal(d.toordinal()) == d`.

`date.weekday()`

Return the day of the week as an integer, where Monday is 0 and Sunday is 6. For example, `date(2002, 12, 4).weekday() == 2`, a Wednesday. See also `isoweekday()`.

`date.isoweekday()`

Return the day of the week as an integer, where Monday is 1 and Sunday is 7. For example, `date(2002, 12, 4).isoweekday() == 3`, a Wednesday. See also `weekday()`, `isocalendar()`.

`date.isocalendar()`

Return a 3-tuple, (ISO year, ISO week number, ISO weekday).

The ISO calendar is a widely used variant of the Gregorian calendar. See <http://www.phys.uu.nl/~vgent/calendar/isocalendar.htm> for a good explanation.

The ISO year consists of 52 or 53 full weeks, and where a week starts on a Monday and ends on a Sunday. The first week of an ISO year is the first (Gregorian) calendar week of a year containing a Thursday. This is called week number 1, and the ISO year of that Thursday is the same as its Gregorian year.

For example, 2004 begins on a Thursday, so the first week of ISO year 2004 begins on Monday, 29 Dec 2003 and ends on Sunday, 4 Jan 2004, so that `date(2003, 12, 29).isocalendar() == (2004, 1, 1)` and `date(2004, 1, 4).isocalendar() == (2004, 1, 7)`.

`date.isoformat()`

Return a string representing the date in ISO 8601 format, 'YYYY-MM-DD'. For example, `date(2002, 12, 4).isoformat() == '2002-12-04'`.

`date.__str__()`

For a date *d*, `str(d)` is equivalent to `d.isoformat()`.

`date.ctime()`

Return a string representing the date, for example `date(2002, 12, 4).ctime() == 'Wed Dec 4 00:00:00 2002'`. `d.ctime()` is equivalent to `time.ctime(time.mktime(d.timetuple()))` on platforms where the native C `ctime()` function (which `time.ctime()` invokes, but which `date.ctime()` does not invoke) conforms to the C standard.

`date.strftime(format)`

Return a string representing the date, controlled by an explicit format string. Format codes referring to hours, minutes or seconds will see 0 values. See section *strftime() and strptime() Behavior*.

Example of counting days to an event:

```
>>> import time
>>> from datetime import date
>>> today = date.today()
>>> today
datetime.date(2007, 12, 5)
>>> today == date.fromtimestamp(time.time())
True
>>> my_birthday = date(today.year, 6, 24)
>>> if my_birthday < today:
...     my_birthday = my_birthday.replace(year=today.year + 1)
>>> my_birthday
datetime.date(2008, 6, 24)
>>> time_to_birthday = abs(my_birthday - today)
>>> time_to_birthday.days
202
```

Example of working with `date`:

```
>>> from datetime import date
>>> d = date.fromordinal(730920) # 730920th day after 1. 1. 0001
>>> d
datetime.date(2002, 3, 11)
>>> t = d.timetuple()
>>> for i in t:
...     print i
2002          # year
3             # month
11           # day
0
0
0
0             # weekday (0 = Monday)
70           # 70th day in the year
-1
>>> ic = d.isocalendar()
>>> for i in ic:
...     print i
2002          # ISO year
11           # ISO week number
1            # ISO day number ( 1 = Monday )
>>> d.isoformat()
'2002-03-11'
>>> d.strftime("%d/%m/%y")
'11/03/02'
>>> d.strftime("%A %d. %B %Y")
'Monday 11. March 2002'
```

## 8.1.4 datetime Objects

A `datetime` object is a single object containing all the information from a `date` object and a `time` object. Like a `date` object, `datetime` assumes the current Gregorian calendar extended in both directions; like a `time` object, `datetime` assumes there are exactly  $3600 \times 24$  seconds in every day.

Constructor:

```
class datetime.datetime (year, month, day[, hour[, minute[, second[, microsecond[, tzinfo ]]]])
```

The year, month and day arguments are required. `tzinfo` may be `None`, or an instance of a `tzinfo` subclass.

The remaining arguments may be ints or longs, in the following ranges:

- `MINYEAR <= year <= MAXYEAR`
- `1 <= month <= 12`
- `1 <= day <= number of days in the given month and year`
- `0 <= hour < 24`
- `0 <= minute < 60`
- `0 <= second < 60`
- `0 <= microsecond < 1000000`

If an argument outside those ranges is given, `ValueError` is raised.

Other constructors, all class methods:

**classmethod** `datetime.today()`

Return the current local `datetime`, with `tzinfo` `None`. This is equivalent to `datetime.fromtimestamp(time.time())`. See also `now()`, `fromtimestamp()`.

**classmethod** `datetime.now([tz])`

Return the current local date and time. If optional argument `tz` is `None` or not specified, this is like `today()`, but, if possible, supplies more precision than can be gotten from going through a `time.time()` timestamp (for example, this may be possible on platforms supplying the C `gettimeofday()` function).

Else `tz` must be an instance of a class `tzinfo` subclass, and the current date and time are converted to `tz`'s time zone. In this case the result is equivalent to `tz.fromutc(datetime.utcnow().replace(tzinfo=tz))`. See also `today()`, `utcnow()`.

**classmethod** `datetime.utcnow()`

Return the current UTC date and time, with `tzinfo` `None`. This is like `now()`, but returns the current UTC date and time, as a naive `datetime` object. See also `now()`.

**classmethod** `datetime.fromtimestamp(timestamp[, tz])`

Return the local date and time corresponding to the POSIX timestamp, such as is returned by `time.time()`. If optional argument `tz` is `None` or not specified, the timestamp is converted to the platform's local date and time, and the returned `datetime` object is naive.

Else `tz` must be an instance of a class `tzinfo` subclass, and the timestamp is converted to `tz`'s time zone. In this case the result is equivalent to `tz.fromutc(datetime.utcnow().replace(tzinfo=tz))`.

`fromtimestamp()` may raise `ValueError`, if the timestamp is out of the range of values supported by the platform C `localtime()` or `gmtime()` functions. It's common for this to be restricted to years in 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by `fromtimestamp()`, and then it's possible to have two timestamps differing by a second that yield identical `datetime` objects. See also `utcfromtimestamp()`.

**classmethod** `datetime.utcfromtimestamp(timestamp)`

Return the UTC `datetime` corresponding to the POSIX timestamp, with `tzinfo` `None`. This may raise `ValueError`, if the timestamp is out of the range of values supported by the platform C `gmtime()` function. It's common for this to be restricted to years in 1970 through 2038. See also `fromtimestamp()`.

**classmethod** `datetime.fromordinal(ordinal)`

Return the `datetime` corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. `ValueError` is raised unless  $1 \leq \text{ordinal} \leq \text{datetime.max.toordinal}()$ . The hour, minute, second and microsecond of the result are all 0, and `tzinfo` is `None`.

**classmethod** `datetime.combine(date, time)`

Return a new `datetime` object whose date components are equal to the given `date` object's, and whose time components and `tzinfo` attributes are equal to the given `time` object's. For any `datetime` object `d`, `d == datetime.combine(d.date(), d.timetz())`. If `date` is a `datetime` object, its time components and `tzinfo` attributes are ignored.

**classmethod** `datetime.strptime(date_string, format)`

Return a `datetime` corresponding to `date_string`, parsed according to `format`. This is equivalent to `datetime(*(time.strptime(date_string, format)[0:6]))`. `ValueError` is raised if the `date_string` and `format` can't be parsed by `time.strptime()` or if it returns a value which isn't a time tuple. See section *strptime() and strptime() Behavior*. New in version 2.5.

Class attributes:

`datetime.min`

The earliest representable `datetime`, `datetime(MINYEAR, 1, 1, tzinfo=None)`.

`datetime.max`

The latest representable `datetime`, `datetime(MAXYEAR, 12, 31, 23, 59, 59, 999999, tzinfo=None)`.

`datetime.resolution`

The smallest possible difference between non-equal `datetime` objects, `timedelta(microseconds=1)`.

Instance attributes (read-only):

`datetime.year`

Between `MINYEAR` and `MAXYEAR` inclusive.

`datetime.month`

Between 1 and 12 inclusive.

`datetime.day`

Between 1 and the number of days in the given month of the given year.

`datetime.hour`

In range (24).

`datetime.minute`

In range (60).

`datetime.second`

In range (60).

`datetime.microsecond`

In range (1000000).

`datetime.tzinfo`

The object passed as the `tzinfo` argument to the `datetime` constructor, or `None` if none was passed.

Supported operations:

Operation	Result
<code>datetime2 = datetime1 + timedelta</code>	(1)
<code>datetime2 = datetime1 - timedelta</code>	(2)
<code>timedelta = datetime1 - datetime2</code>	(3)
<code>datetime1 &lt; datetime2</code>	Compares <code>datetime</code> to <code>datetime</code> . (4)

1. `datetime2` is a duration of `timedelta` removed from `datetime1`, moving forward in time if `timedelta.days > 0`, or backward if `timedelta.days < 0`. The result has the same `tzinfo` attribute as the input `datetime`, and `datetime2 - datetime1 == timedelta` after. `OverflowError` is raised if `datetime2.year` would be smaller than `MINYEAR` or larger than `MAXYEAR`. Note that no time zone adjustments are done even if the input is an aware object.

2. Computes the `datetime2` such that `datetime2 + timedelta == datetime1`. As for addition, the result has the same `tzinfo` attribute as the input `datetime`, and no time zone adjustments are done even if the input is aware. This isn't quite equivalent to `datetime1 + (-timedelta)`, because `-timedelta` in isolation can overflow in cases where `datetime1 - timedelta` does not.

3. Subtraction of a `datetime` from a `datetime` is defined only if both operands are naive, or if both are aware. If one is aware and the other is naive, `TypeError` is raised.

If both are naive, or both are aware and have the same `tzinfo` attribute, the `tzinfo` attributes are ignored, and the result is a `timedelta` object `t` such that `datetime2 + t == datetime1`. No time zone adjustments are done in this case.

If both are aware and have different `tzinfo` attributes, `a-b` acts as if `a` and `b` were first converted to naive UTC datetimes first. The result is `(a.replace(tzinfo=None) - a.utcoffset()) - (b.replace(tzinfo=None) - b.utcoffset())` except that the implementation never overflows.

4. *datetime1* is considered less than *datetime2* when *datetime1* precedes *datetime2* in time.

If one comparand is naive and the other is aware, `TypeError` is raised. If both comparands are aware, and have the same `tzinfo` attribute, the common `tzinfo` attribute is ignored and the base datetimes are compared. If both comparands are aware and have different `tzinfo` attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from `self.utcoffset()`).

---

**Note:** In order to stop comparison from falling back to the default scheme of comparing object addresses, datetime comparison normally raises `TypeError` if the other comparand isn't also a `datetime` object. However, `NotImplemented` is returned instead if the other comparand has a `timetuple()` attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a `datetime` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.

---

`datetime` objects can be used as dictionary keys. In Boolean contexts, all `datetime` objects are considered to be true.

Instance methods:

`datetime.date()`

Return `date` object with same year, month and day.

`datetime.time()`

Return `time` object with same hour, minute, second and microsecond. `tzinfo` is `None`. See also method `timetz()`.

`datetime.timetz()`

Return `time` object with same hour, minute, second, microsecond, and `tzinfo` attributes. See also method `time()`.

`datetime.replace([year[, month[, day[, hour[, minute[, second[, microsecond[, tzinfo]]]]]]])`

Return a datetime with the same attributes, except for those attributes given new values by whichever keyword arguments are specified. Note that `tzinfo=None` can be specified to create a naive datetime from an aware datetime with no conversion of date and time data.

`datetime.astimezone(tz)`

Return a `datetime` object with new `tzinfo` attribute `tz`, adjusting the date and time data so the result is the same UTC time as *self*, but in *tz*'s local time.

*tz* must be an instance of a `tzinfo` subclass, and its `utcoffset()` and `dst()` methods must not return `None`. *self* must be aware (`self.tzinfo` must not be `None`, and `self.utcoffset()` must not return `None`).

If `self.tzinfo` is *tz*, `self.astimezone(tz)` is equal to *self*: no adjustment of date or time data is performed. Else the result is local time in time zone *tz*, representing the same UTC time as *self*: after `astz = dt.astimezone(tz)`, `astz - astz.utcoffset()` will usually have the same date and time data as `dt - dt.utcoffset()`. The discussion of class `tzinfo` explains the cases at Daylight Saving Time transition boundaries where this cannot be achieved (an issue only if *tz* models both standard and daylight time).

If you merely want to attach a time zone object *tz* to a datetime *dt* without adjustment of date and time data, use `dt.replace(tzinfo=tz)`. If you merely want to remove the time zone object from an aware datetime *dt* without conversion of date and time data, use `dt.replace(tzinfo=None)`.

Note that the default `tzinfo.fromutc()` method can be overridden in a `tzinfo` subclass to affect the result returned by `astimezone()`. Ignoring error cases, `astimezone()` acts like:

```
def astimezone(self, tz):
    if self.tzinfo is tz:
        return self
```

```
# Convert self to UTC, and attach the new time zone object.
utc = (self - self.utcoffset()).replace(tzinfo=tz)
# Convert from UTC to tz's local time.
return tz.fromutc(utc)
```

`datetime.utcoffset()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.utcoffset(self)`, and raises an exception if the latter doesn't return `None`, or a `timedelta` object representing a whole number of minutes with magnitude less than one day.

`datetime.dst()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.dst(self)`, and raises an exception if the latter doesn't return `None`, or a `timedelta` object representing a whole number of minutes with magnitude less than one day.

`datetime.tzname()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.tzname(self)`, raises an exception if the latter doesn't return `None` or a string object,

`datetime.timetuple()`

Return a `time.struct_time` such as returned by `time.localtime().d.timetuple()` is equivalent to `time.struct_time((d.year, d.month, d.day, d.hour, d.minute, d.second, d.weekday(), yday, dst))`, where `yday = d.toordinal() - date(d.year, 1, 1).toordinal() + 1` is the day number within the current year starting with 1 for January 1st. The `tm_isdst` flag of the result is set according to the `dst()` method: `tzinfo` is `None` or `dst()` returns `None`, `tm_isdst` is set to `-1`; else if `dst()` returns a non-zero value, `tm_isdst` is set to `1`; else `tm_isdst` is set to `0`.

`datetime.utctimetuple()`

If `datetime` instance `d` is naive, this is the same as `d.timetuple()` except that `tm_isdst` is forced to `0` regardless of what `d.dst()` returns. DST is never in effect for a UTC time.

If `d` is aware, `d` is normalized to UTC time, by subtracting `d.utcoffset()`, and a `time.struct_time` for the normalized time is returned. `tm_isdst` is forced to `0`. Note that the result's `tm_year` member may be `MINYEAR-1` or `MAXYEAR+1`, if `d.year` was `MINYEAR` or `MAXYEAR` and UTC adjustment spills over a year boundary.

`datetime.toordinal()`

Return the proleptic Gregorian ordinal of the date. The same as `self.date().toordinal()`.

`datetime.weekday()`

Return the day of the week as an integer, where Monday is 0 and Sunday is 6. The same as `self.date().weekday()`. See also `isoweekday()`.

`datetime.isoweekday()`

Return the day of the week as an integer, where Monday is 1 and Sunday is 7. The same as `self.date().isoweekday()`. See also `weekday()`, `isocalendar()`.

`datetime.isocalendar()`

Return a 3-tuple, (ISO year, ISO week number, ISO weekday). The same as `self.date().isocalendar()`.

`datetime.isoformat([sep])`

Return a string representing the date and time in ISO 8601 format, `YYYY-MM-DDTHH:MM:SS.mmmmmm` or, if `microsecond` is 0, `YYYY-MM-DDTHH:MM:SS`

If `utcoffset()` does not return `None`, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: `YYYY-MM-DDTHH:MM:SS.mmmmmm+HH:MM` or, if `microsecond` is 0 `YYYY-MM-DDTHH:MM:SS+HH:MM`

The optional argument *sep* (default 'T') is a one-character separator, placed between the date and time portions of the result. For example,

```
>>> from datetime import tzinfo, timedelta, datetime
>>> class TZ(tzinfo):
...     def utcoffset(self, dt): return timedelta(minutes=-399)
...
>>> datetime(2002, 12, 25, tzinfo=TZ()).isoformat(' ')
'2002-12-25 00:00:00-06:39'
```

`datetime.__str__()`

For a `datetime` instance *d*, `str(d)` is equivalent to `d.isoformat(' ')`.

`datetime.ctime()`

Return a string representing the date and time, for example `datetime(2002, 12, 4, 20, 30, 40).ctime() == 'Wed Dec 4 20:30:40 2002'`. `d.ctime()` is equivalent to `time.ctime(time.mktime(d.timetuple()))` on platforms where the native C `ctime()` function (which `time.ctime()` invokes, but which `datetime.ctime()` does not invoke) conforms to the C standard.

`datetime.strftime(format)`

Return a string representing the date and time, controlled by an explicit format string. See section *strftime() and strptime() Behavior*.

Examples of working with datetime objects:

```
>>> from datetime import datetime, date, time
>>> # Using datetime.combine()
>>> d = date(2005, 7, 14)
>>> t = time(12, 30)
>>> datetime.combine(d, t)
datetime.datetime(2005, 7, 14, 12, 30)
>>> # Using datetime.now() or datetime.utcnow()
>>> datetime.now()
datetime.datetime(2007, 12, 6, 16, 29, 43, 79043) # GMT +1
>>> datetime.utcnow()
datetime.datetime(2007, 12, 6, 15, 29, 43, 79060)
>>> # Using datetime.strptime()
>>> dt = datetime.strptime("21/11/06 16:30", "%d/%m/%y %H:%M")
>>> dt
datetime.datetime(2006, 11, 21, 16, 30)
>>> # Using datetime.timetuple() to get tuple of all attributes
>>> tt = dt.timetuple()
>>> for it in tt:
...     print it
...
2006 # year
11 # month
21 # day
16 # hour
30 # minute
0 # second
1 # weekday (0 = Monday)
325 # number of days since 1st January
-1 # dst - method tzinfo.dst() returned None
>>> # Date in ISO format
```

```
>>> ic = dt.isocalendar()
>>> for it in ic:
...     print it
...
2006      # ISO year
47        # ISO week
2         # ISO weekday
>>> # Formatting datetime
>>> dt.strftime("%A, %d. %B %Y %I:%M%p")
'Tuesday, 21. November 2006 04:30PM'
```

Using datetime with tzinfo:

```
>>> from datetime import timedelta, datetime, tzinfo
>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1) + self.dst(dt)
...     def dst(self, dt):
...         # DST starts last Sunday in March
...         d = datetime(dt.year, 4, 1) # ends last Sunday in October
...         self.dston = d - timedelta(days=d.weekday() + 1)
...         d = datetime(dt.year, 11, 1)
...         self.dstoff = d - timedelta(days=d.weekday() + 1)
...         if self.dston <= dt.replace(tzinfo=None) < self.dstoff:
...             return timedelta(hours=1)
...         else:
...             return timedelta(0)
...     def tzname(self, dt):
...         return "GMT +1"
...
>>> class GMT2(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=2) + self.dst(dt)
...     def dst(self, dt):
...         d = datetime(dt.year, 4, 1)
...         self.dston = d - timedelta(days=d.weekday() + 1)
...         d = datetime(dt.year, 11, 1)
...         self.dstoff = d - timedelta(days=d.weekday() + 1)
...         if self.dston <= dt.replace(tzinfo=None) < self.dstoff:
...             return timedelta(hours=1)
...         else:
...             return timedelta(0)
...     def tzname(self, dt):
...         return "GMT +2"
...
>>> gmt1 = GMT1()
>>> # Daylight Saving Time
>>> dt1 = datetime(2006, 11, 21, 16, 30, tzinfo=gmt1)
>>> dt1.dst()
datetime.timedelta(0)
>>> dt1.utcoffset()
datetime.timedelta(0, 3600)
>>> dt2 = datetime(2006, 6, 14, 13, 0, tzinfo=gmt1)
>>> dt2.dst()
datetime.timedelta(0, 3600)
```

```

>>> dt2.utcoffset()
datetime.timedelta(0, 7200)
>>> # Convert datetime to another time zone
>>> dt3 = dt2.astimezone(GMT2())
>>> dt3
datetime.datetime(2006, 6, 14, 14, 0, tzinfo=<GMT2 object at 0x...>)
>>> dt2
datetime.datetime(2006, 6, 14, 13, 0, tzinfo=<GMT1 object at 0x...>)
>>> dt2.utctimetuple() == dt3.utctimetuple()
True

```

### 8.1.5 time Objects

A time object represents a (local) time of day, independent of any particular day, and subject to adjustment via a `tzinfo` object.

**class** `datetime.time` (*hour* [, *minute* [, *second* [, *microsecond* [, *tzinfo* ] ] ] ] )

All arguments are optional. *tzinfo* may be `None`, or an instance of a `tzinfo` subclass. The remaining arguments may be ints or longs, in the following ranges:

- 0 <= hour < 24
- 0 <= minute < 60
- 0 <= second < 60
- 0 <= microsecond < 1000000.

If an argument outside those ranges is given, `ValueError` is raised. All default to 0 except *tzinfo*, which defaults to `None`.

Class attributes:

`time.min`

The earliest representable `time`, `time(0, 0, 0, 0)`.

`time.max`

The latest representable `time`, `time(23, 59, 59, 999999)`.

`time.resolution`

The smallest possible difference between non-equal `time` objects, `timedelta(microseconds=1)`, although note that arithmetic on `time` objects is not supported.

Instance attributes (read-only):

`time.hour`

In range (24).

`time.minute`

In range (60).

`time.second`

In range (60).

`time.microsecond`

In range (1000000).

`time.tzinfo`

The object passed as the *tzinfo* argument to the `time` constructor, or `None` if none was passed.

Supported operations:

- comparison of `time` to `time`, where *a* is considered less than *b* when *a* precedes *b* in time. If one comparand is naive and the other is aware, `TypeError` is raised. If both comparands are aware, and have the same `tzinfo` attribute, the common `tzinfo` attribute is ignored and the base times are compared. If both comparands are aware and have different `tzinfo` attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from `self.utcoffset()`). In order to stop mixed-type comparisons from falling back to the default comparison by object address, when a `time` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.
- hash, use as dict key
- efficient pickling
- in Boolean contexts, a `time` object is considered to be true if and only if, after converting it to minutes and subtracting `utcoffset()` (or 0 if that's `None`), the result is non-zero.

Instance methods:

`time.replace([hour[, minute[, second[, microsecond[, tzinfo]]]])`

Return a `time` with the same value, except for those attributes given new values by whichever keyword arguments are specified. Note that `tzinfo=None` can be specified to create a naive `time` from an aware `time`, without conversion of the time data.

`time.isoformat()`

Return a string representing the time in ISO 8601 format, `HH:MM:SS.mmmmmm` or, if `self.microsecond` is 0, `HH:MM:SS`. If `utcoffset()` does not return `None`, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: `HH:MM:SS.mmmmmm+HH:MM` or, if `self.microsecond` is 0, `HH:MM:SS+HH:MM`

`time.__str__()`

For a time *t*, `str(t)` is equivalent to `t.isoformat()`.

`time.strftime(format)`

Return a string representing the time, controlled by an explicit format string. See section *strftime() and strptime() Behavior*.

`time.utcoffset()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.utcoffset(None)`, and raises an exception if the latter doesn't return `None` or a `timedelta` object representing a whole number of minutes with magnitude less than one day.

`time.dst()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.dst(None)`, and raises an exception if the latter doesn't return `None`, or a `timedelta` object representing a whole number of minutes with magnitude less than one day.

`time.tzname()`

If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.tzname(None)`, or raises an exception if the latter doesn't return `None` or a string object.

Example:

```
>>> from datetime import time, tzinfo
>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1)
...     def dst(self, dt):
...         return timedelta(0)
...     def tzname(self, dt):
...         return "Europe/Prague"
... 
```

```

>>> t = time(12, 10, 30, tzinfo=GMT1())
>>> t
datetime.time(12, 10, 30, tzinfo=<GMT1 object at 0x...>)
>>> gmt = GMT1()
>>> t.isoformat()
'12:10:30+01:00'
>>> t.dst()
datetime.timedelta(0)
>>> t.tzname()
'Europe/Prague'
>>> t.strftime("%H:%M:%S %Z")
'12:10:30 Europe/Prague'

```

### 8.1.6 tzinfo Objects

`tzinfo` is an abstract base class, meaning that this class should not be instantiated directly. You need to derive a concrete subclass, and (at least) supply implementations of the standard `tzinfo` methods needed by the `datetime` methods you use. The `datetime` module does not supply any concrete subclasses of `tzinfo`.

An instance of (a concrete subclass of) `tzinfo` can be passed to the constructors for `datetime` and `time` objects. The latter objects view their attributes as being in local time, and the `tzinfo` object supports methods revealing offset of local time from UTC, the name of the time zone, and DST offset, all relative to a date or time object passed to them.

Special requirement for pickling: A `tzinfo` subclass must have an `__init__()` method that can be called with no arguments, else it can be pickled but possibly not unpickled again. This is a technical requirement that may be relaxed in the future.

A concrete subclass of `tzinfo` may need to implement the following methods. Exactly which methods are needed depends on the uses made of aware `datetime` objects. If in doubt, simply implement all of them.

`tzinfo.utcoffset` (*self*, *dt*)

Return offset of local time from UTC, in minutes east of UTC. If local time is west of UTC, this should be negative. Note that this is intended to be the total offset from UTC; for example, if a `tzinfo` object represents both time zone and DST adjustments, `utcoffset()` should return their sum. If the UTC offset isn't known, return `None`. Else the value returned must be a `timedelta` object specifying a whole number of minutes in the range -1439 to 1439 inclusive (1440 = 24\*60; the magnitude of the offset must be less than one day). Most implementations of `utcoffset()` will probably look like one of these two:

```

return CONSTANT # fixed-offset class
return CONSTANT + self.dst(dt) # daylight-aware class

```

If `utcoffset()` does not return `None`, `dst()` should not return `None` either.

The default implementation of `utcoffset()` raises `NotImplementedError`.

`tzinfo.dst` (*self*, *dt*)

Return the daylight saving time (DST) adjustment, in minutes east of UTC, or `None` if DST information isn't known. Return `timedelta(0)` if DST is not in effect. If DST is in effect, return the offset as a `timedelta` object (see `utcoffset()` for details). Note that DST offset, if applicable, has already been added to the UTC offset returned by `utcoffset()`, so there's no need to consult `dst()` unless you're interested in obtaining DST info separately. For example, `datetime.timetuple()` calls its `tzinfo` attribute's `dst()` method to determine how the `tm_isdst` flag should be set, and `tzinfo.fromutc()` calls `dst()` to account for DST changes when crossing time zones.

An instance *tz* of a `tzinfo` subclass that models both standard and daylight times must be consistent in this sense:

```
tz.utcoffset(dt) - tz.dst(dt)
```

must return the same result for every `datetime` *dt* with `dt.tzinfo == tz`. For sane `tzinfo` subclasses, this expression yields the time zone’s “standard offset”, which should not depend on the date or the time, but only on geographic location. The implementation of `datetime.astimezone()` relies on this, but cannot detect violations; it’s the programmer’s responsibility to ensure it. If a `tzinfo` subclass cannot guarantee this, it may be able to override the default implementation of `tzinfo.fromutc()` to work correctly with `astimezone()` regardless.

Most implementations of `dst()` will probably look like one of these two:

```
def dst(self, dt):
    # a fixed-offset class: doesn't account for DST
    return timedelta(0)
```

or

```
def dst(self, dt):
    # Code to set dston and dstoff to the time zone's DST
    # transition times based on the input dt.year, and expressed
    # in standard local time. Then

    if dston <= dt.replace(tzinfo=None) < dstoff:
        return timedelta(hours=1)
    else:
        return timedelta(0)
```

The default implementation of `dst()` raises `NotImplementedError`.

`tzinfo.tzname(self, dt)`

Return the time zone name corresponding to the `datetime` object *dt*, as a string. Nothing about string names is defined by the `datetime` module, and there’s no requirement that it mean anything in particular. For example, “GMT”, “UTC”, “-500”, “-5:00”, “EDT”, “US/Eastern”, “America/New York” are all valid replies. Return `None` if a string name isn’t known. Note that this is a method rather than a fixed string primarily because some `tzinfo` subclasses will wish to return different names depending on the specific value of *dt* passed, especially if the `tzinfo` class is accounting for daylight time.

The default implementation of `tzname()` raises `NotImplementedError`.

These methods are called by a `datetime` or `time` object, in response to their methods of the same names. A `datetime` object passes itself as the argument, and a `time` object passes `None` as the argument. A `tzinfo` subclass’s methods should therefore be prepared to accept a *dt* argument of `None`, or of class `datetime`.

When `None` is passed, it’s up to the class designer to decide the best response. For example, returning `None` is appropriate if the class wishes to say that time objects don’t participate in the `tzinfo` protocols. It may be more useful for `utcoffset(None)` to return the standard UTC offset, as there is no other convention for discovering the standard offset.

When a `datetime` object is passed in response to a `datetime` method, `dt.tzinfo` is the same object as *self*. `tzinfo` methods can rely on this, unless user code calls `tzinfo` methods directly. The intent is that the `tzinfo` methods interpret *dt* as being in local time, and not need worry about objects in other timezones.

There is one more `tzinfo` method that a subclass may wish to override:

`tzinfo.fromutc(self, dt)`

This is called from the default `datetime.astimezone()` implementation. When called from that, `dt.tzinfo` is *self*, and *dt*’s date and time data are to be viewed as expressing a UTC time. The purpose of `fromutc()` is to adjust the date and time data, returning an equivalent `datetime` in *self*’s local time.

Most `tzinfo` subclasses should be able to inherit the default `fromutc()` implementation without problems. It's strong enough to handle fixed-offset time zones, and time zones accounting for both standard and daylight time, and the latter even if the DST transition times differ in different years. An example of a time zone the default `fromutc()` implementation may not handle correctly in all cases is one where the standard offset (from UTC) depends on the specific date and time passed, which can happen for political reasons. The default implementations of `astimezone()` and `fromutc()` may not produce the result you want if the result is one of the hours straddling the moment the standard offset changes.

Skipping code for error cases, the default `fromutc()` implementation acts like:

```
def fromutc(self, dt):
    # raise ValueError if dt.tzinfo is not self
    dtoff = dt.utcoffset()
    dtdst = dt.dst()
    # raise ValueError if dtoff is None or dtdst is None
    delta = dtoff - dtdst # this is self's standard offset
    if delta:
        dt += delta # convert to standard local time
        dtdst = dt.dst()
        # raise ValueError if dtdst is None
    if dtdst:
        return dt + dtdst
    else:
        return dt
```

Example `tzinfo` classes:

```
from datetime import tzinfo, timedelta, datetime

ZERO = timedelta(0)
HOUR = timedelta(hours=1)

# A UTC class.

class UTC(tzinfo):
    """UTC"""

    def utcoffset(self, dt):
        return ZERO

    def tzname(self, dt):
        return "UTC"

    def dst(self, dt):
        return ZERO

utc = UTC()

# A class building tzinfo objects for fixed-offset time zones.
# Note that FixedOffset(0, "UTC") is a different way to build a
# UTC tzinfo object.

class FixedOffset(tzinfo):
    """Fixed offset in minutes east from UTC."""
```

```
def __init__(self, offset, name):
    self.__offset = timedelta(minutes = offset)
    self.__name = name

def utcoffset(self, dt):
    return self.__offset

def tzname(self, dt):
    return self.__name

def dst(self, dt):
    return ZERO

# A class capturing the platform's idea of local time.

import time as _time

STDOFFSET = timedelta(seconds = -_time.timezone)
if _time.daylight:
    DSTOFFSET = timedelta(seconds = -_time.altzone)
else:
    DSTOFFSET = STDOFFSET

DSTDIFF = DSTOFFSET - STDOFFSET

class LocalTimezone(tzinfo):

    def utcoffset(self, dt):
        if self._isdst(dt):
            return DSTOFFSET
        else:
            return STDOFFSET

    def dst(self, dt):
        if self._isdst(dt):
            return DSTDIFF
        else:
            return ZERO

    def tzname(self, dt):
        return _time.tzname[self._isdst(dt)]

    def _isdst(self, dt):
        tt = (dt.year, dt.month, dt.day,
              dt.hour, dt.minute, dt.second,
              dt.weekday(), 0, 0)
        stamp = _time.mktime(tt)
        tt = _time.localtime(stamp)
        return tt.tm_isdst > 0

Local = LocalTimezone()
```

*# A complete implementation of current DST rules for major US time zones.*

```

def first_sunday_on_or_after(dt):
    days_to_go = 6 - dt.weekday()
    if days_to_go:
        dt += timedelta(days_to_go)
    return dt

# US DST Rules
#
# This is a simplified (i.e., wrong for a few cases) set of rules for US
# DST start and end times. For a complete and up-to-date set of DST rules
# and timezone definitions, visit the Olson Database (or try pytz):
# http://www.twinsun.com/tz/tz-link.htm
# http://sourceforge.net/projects/pytz/ (might not be up-to-date)
#
# In the US, since 2007, DST starts at 2am (standard time) on the second
# Sunday in March, which is the first Sunday on or after Mar 8.
DSTSTART_2007 = datetime(1, 3, 8, 2)
# and ends at 2am (DST time; 1am standard time) on the first Sunday of Nov.
DSTEND_2007 = datetime(1, 11, 1, 1)
# From 1987 to 2006, DST used to start at 2am (standard time) on the first
# Sunday in April and to end at 2am (DST time; 1am standard time) on the last
# Sunday of October, which is the first Sunday on or after Oct 25.
DSTSTART_1987_2006 = datetime(1, 4, 1, 2)
DSTEND_1987_2006 = datetime(1, 10, 25, 1)
# From 1967 to 1986, DST used to start at 2am (standard time) on the last
# Sunday in April (the one on or after April 24) and to end at 2am (DST time;
# 1am standard time) on the last Sunday of October, which is the first Sunday
# on or after Oct 25.
DSTSTART_1967_1986 = datetime(1, 4, 24, 2)
DSTEND_1967_1986 = DSTEND_1987_2006

class USTimeZone(tzinfo):

    def __init__(self, hours, reprname, stdname, dstname):
        self.stdoffset = timedelta(hours=hours)
        self.reprname = reprname
        self.stdname = stdname
        self.dstname = dstname

    def __repr__(self):
        return self.reprname

    def tzname(self, dt):
        if self.dst(dt):
            return self.dstname
        else:
            return self.stdname

    def utcoffset(self, dt):
        return self.stdoffset + self.dst(dt)

    def dst(self, dt):

```

```

if dt is None or dt.tzinfo is None:
    # An exception may be sensible here, in one or both cases.
    # It depends on how you want to treat them. The default
    # fromutc() implementation (called by the default astimezone()
    # implementation) passes a datetime with dt.tzinfo is self.
    return ZERO
assert dt.tzinfo is self

# Find start and end times for US DST. For years before 1967, return
# ZERO for no DST.
if 2006 < dt.year:
    dststart, dstend = DSTSTART_2007, DSTEND_2007
elif 1986 < dt.year < 2007:
    dststart, dstend = DSTSTART_1987_2006, DSTEND_1987_2006
elif 1966 < dt.year < 1987:
    dststart, dstend = DSTSTART_1967_1986, DSTEND_1967_1986
else:
    return ZERO

start = first_sunday_on_or_after(dststart.replace(year=dt.year))
end = first_sunday_on_or_after(dstend.replace(year=dt.year))

# Can't compare naive to aware objects, so strip the timezone from
# dt first.
if start <= dt.replace(tzinfo=None) < end:
    return HOUR
else:
    return ZERO

```

```

Eastern = USTimeZone(-5, "Eastern", "EST", "EDT")
Central = USTimeZone(-6, "Central", "CST", "CDT")
Mountain = USTimeZone(-7, "Mountain", "MST", "MDT")
Pacific = USTimeZone(-8, "Pacific", "PST", "PDT")

```

Note that there are unavoidable subtleties twice per year in a `tzinfo` subclass accounting for both standard and daylight time, at the DST transition points. For concreteness, consider US Eastern (UTC -0500), where EDT begins the minute after 1:59 (EST) on the second Sunday in March, and ends the minute after 1:59 (EDT) on the first Sunday in November:

```

UTC    3:MM  4:MM  5:MM  6:MM  7:MM  8:MM
EST   22:MM 23:MM  0:MM  1:MM  2:MM  3:MM
EDT   23:MM  0:MM  1:MM  2:MM  3:MM  4:MM

start  22:MM 23:MM  0:MM  1:MM  3:MM  4:MM

end    23:MM  0:MM  1:MM  1:MM  2:MM  3:MM

```

When DST starts (the “start” line), the local wall clock leaps from 1:59 to 3:00. A wall time of the form 2:MM doesn’t really make sense on that day, so `astimezone(Eastern)` won’t deliver a result with `hour == 2` on the day DST begins. In order for `astimezone()` to make this guarantee, the `tzinfo.dst()` method must consider times in the “missing hour” (2:MM for Eastern) to be in daylight time.

When DST ends (the “end” line), there’s a potentially worse problem: there’s an hour that can’t be spelled unambiguously in local wall time: the last hour of daylight time. In Eastern, that’s times of the form 5:MM UTC on the day daylight time ends. The local wall clock leaps from 1:59 (daylight time) back to 1:00 (standard time) again. Local times of the form 1:MM are ambiguous. `astimezone()` mimics the local clock’s behavior by mapping two adjacent

UTC hours into the same local hour then. In the Eastern example, UTC times of the form 5:MM and 6:MM both map to 1:MM when converted to Eastern. In order for `astimezone()` to make this guarantee, the `tzinfo.dst()` method must consider times in the “repeated hour” to be in standard time. This is easily arranged, as in the example, by expressing DST switch times in the time zone’s standard local time.

Applications that can’t bear such ambiguities should avoid using hybrid `tzinfo` subclasses; there are no ambiguities when using UTC, or any other fixed-offset `tzinfo` subclass (such as a class representing only EST (fixed offset -5 hours), or only EDT (fixed offset -4 hours)).

#### See Also:

**pytz** The standard library has no `tzinfo` instances except for UTC, but there exists a third-party library which brings the *IANA timezone database* (also known as the Olson database) to Python: `pytz`.

`pytz` contains up-to-date information and its usage is recommended.

**IANA timezone database** The Time Zone Database (often called `tz` or `zoneinfo`) contains code and data that represent the history of local time for many representative locations around the globe. It is updated periodically to reflect changes made by political bodies to time zone boundaries, UTC offsets, and daylight-saving rules.

## 8.1.7 `strftime()` and `strptime()` Behavior

`date`, `datetime`, and `time` objects all support a `strftime(format)` method, to create a string representing the time under the control of an explicit format string. Broadly speaking, `d.strftime(fmt)` acts like the `time` module’s `time.strftime(fmt, d.timetuple())` although not all objects support a `timetuple()` method.

Conversely, the `datetime.strptime()` class method creates a `datetime` object from a string representing a date and time and a corresponding format string. `datetime.strptime(date_string, format)` is equivalent to `datetime(*(time.strptime(date_string, format)[0:6]))`.

For `time` objects, the format codes for year, month, and day should not be used, as time objects have no such values. If they’re used anyway, 1900 is substituted for the year, and 1 for the month and day.

For `date` objects, the format codes for hours, minutes, seconds, and microseconds should not be used, as `date` objects have no such values. If they’re used anyway, 0 is substituted for them. New in version 2.6: `time` and `datetime` objects support a `%f` format code which expands to the number of microseconds in the object, zero-padded on the left to six places. For a naive object, the `%z` and `%Z` format codes are replaced by empty strings.

For an aware object:

**%z** `utcoffset()` is transformed into a 5-character string of the form `+HHMM` or `-HHMM`, where `HH` is a 2-digit string giving the number of UTC offset hours, and `MM` is a 2-digit string giving the number of UTC offset minutes. For example, if `utcoffset()` returns `timedelta(hours=-3, minutes=-30)`, `%z` is replaced with the string `'-0330'`.

**%Z** If `tzname()` returns `None`, `%Z` is replaced by an empty string. Otherwise `%Z` is replaced by the returned value, which must be a string.

The full set of format codes supported varies across platforms, because Python calls the platform C library’s `strftime()` function, and platform variations are common.

The following is a list of all the format codes that the C standard (1989 version) requires, and these work on all platforms with a standard C implementation. Note that the 1999 version of the C standard added additional format codes.

The exact range of years for which `strftime()` works also varies across platforms. Regardless of platform, years before 1900 cannot be used.

Di- rec- tive	Meaning	Notes
%a	Locale's abbreviated weekday name.	
%A	Locale's full weekday name.	
%b	Locale's abbreviated month name.	
%B	Locale's full month name.	
%c	Locale's appropriate date and time representation.	
%d	Day of the month as a decimal number [01,31].	
%f	Microsecond as a decimal number [0,999999], zero-padded on the left	(1)
%H	Hour (24-hour clock) as a decimal number [00,23].	
%I	Hour (12-hour clock) as a decimal number [01,12].	
%j	Day of the year as a decimal number [001,366].	
%m	Month as a decimal number [01,12].	
%M	Minute as a decimal number [00,59].	
%p	Locale's equivalent of either AM or PM.	(2)
%S	Second as a decimal number [00,61].	(3)
%U	Week number of the year (Sunday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Sunday are considered to be in week 0.	(4)
%w	Weekday as a decimal number [0(Sunday),6].	
%W	Week number of the year (Monday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Monday are considered to be in week 0.	(4)
%x	Locale's appropriate date representation.	
%X	Locale's appropriate time representation.	
%y	Year without century as a decimal number [00,99].	
%Y	Year with century as a decimal number.	
%z	UTC offset in the form +HHMM or -HHMM (empty string if the the object is naive).	(5)
%Z	Time zone name (empty string if the object is naive).	
%%	A literal '%' character.	

Notes:

1. When used with the `strptime()` method, the `%f` directive accepts from one to six digits and zero pads on the right. `%f` is an extension to the set of format characters in the C standard (but implemented separately in datetime objects, and therefore always available).
2. When used with the `strptime()` method, the `%p` directive only affects the output hour field if the `%I` directive is used to parse the hour.
3. The range really is 0 to 61; according to the Posix standard this accounts for leap seconds and the (very rare) double leap seconds. The `time` module may produce and does accept leap seconds since it is based on the Posix standard, but the `datetime` module does not accept leap seconds in `strptime()` input nor will it produce them in `strftime()` output.
4. When used with the `strptime()` method, `%U` and `%W` are only used in calculations when the day of the week and the year are specified.
5. For example, if `utcoffset()` returns `timedelta(hours=-3, minutes=-30)`, `%z` is replaced with the string `'-0330'`.

## 8.2 calendar — General calendar-related functions

Source code: [Lib/calendar.py](#)

This module allows you to output calendars like the Unix `cal` program, and provides additional useful functions related to the calendar. By default, these calendars have Monday as the first day of the week, and Sunday as the last (the European convention). Use `setfirstweekday()` to set the first day of the week to Sunday (6) or to any other weekday. Parameters that specify dates are given as integers. For related functionality, see also the `datetime` and `time` modules.

Most of these functions and classes rely on the `datetime` module which uses an idealized calendar, the current Gregorian calendar indefinitely extended in both directions. This matches the definition of the “proleptic Gregorian” calendar in Dershowitz and Reingold’s book “Calendrical Calculations”, where it’s the base calendar for all computations.

**class** `calendar.Calendar` (`[firstweekday]`)

Creates a `Calendar` object. `firstweekday` is an integer specifying the first day of the week. 0 is Monday (the default), 6 is Sunday.

A `Calendar` object provides several methods that can be used for preparing the calendar data for formatting. This class doesn’t do any formatting itself. This is the job of subclasses. New in version 2.5. `Calendar` instances have the following methods:

**iterweekdays** ()

Return an iterator for the week day numbers that will be used for one week. The first value from the iterator will be the same as the value of the `firstweekday` property.

**itermonthdates** (`year`, `month`)

Return an iterator for the month `month` (1-12) in the year `year`. This iterator will return all days (as `datetime.date` objects) for the month and all days before the start of the month or after the end of the month that are required to get a complete week.

**itermonthdays2** (`year`, `month`)

Return an iterator for the month `month` in the year `year` similar to `itermonthdates()`. Days returned will be tuples consisting of a day number and a week day number.

**itermonthdays** (`year`, `month`)

Return an iterator for the month `month` in the year `year` similar to `itermonthdates()`. Days returned will simply be day numbers.

**monthdatescalendar** (`year`, `month`)

Return a list of the weeks in the month `month` of the `year` as full weeks. Weeks are lists of seven `datetime.date` objects.

**monthdays2calendar** (`year`, `month`)

Return a list of the weeks in the month `month` of the `year` as full weeks. Weeks are lists of seven tuples of day numbers and weekday numbers.

**monthdayscalendar** (`year`, `month`)

Return a list of the weeks in the month `month` of the `year` as full weeks. Weeks are lists of seven day numbers.

**yeardatescalendar** (`year`[, `width`])

Return the data for the specified year ready for formatting. The return value is a list of month rows. Each month row contains up to `width` months (defaulting to 3). Each month contains between 4 and 6 weeks and each week contains 1–7 days. Days are `datetime.date` objects.

**yeardays2calendar** (`year`[, `width`])

Return the data for the specified year ready for formatting (similar to `yeardatescalendar()`). Entries in the week lists are tuples of day numbers and weekday numbers. Day numbers outside this month are zero.

**yeardayscalendar** (`year`[, `width`])

Return the data for the specified year ready for formatting (similar to `yeardatescalendar()`). Entries

in the week lists are day numbers. Day numbers outside this month are zero.

**class** `calendar.TextCalendar` (`[firstweekday]`)

This class can be used to generate plain text calendars. New in version 2.5. `TextCalendar` instances have the following methods:

**formatmonth** (`theyear, themonth`, `[w, l]`)

Return a month's calendar in a multi-line string. If `w` is provided, it specifies the width of the date columns, which are centered. If `l` is given, it specifies the number of lines that each week will use. Depends on the first weekday as specified in the constructor or set by the `setfirstweekday()` method.

**prmonth** (`theyear, themonth`, `[w, l]`)

Print a month's calendar as returned by `formatmonth()`.

**formatyear** (`theyear`, `[w, l, c, m]`)

Return a `m`-column calendar for an entire year as a multi-line string. Optional parameters `w`, `l`, and `c` are for date column width, lines per week, and number of spaces between month columns, respectively. Depends on the first weekday as specified in the constructor or set by the `setfirstweekday()` method. The earliest year for which a calendar can be generated is platform-dependent.

**pryear** (`theyear`, `[w, l, c, m]`)

Print the calendar for an entire year as returned by `formatyear()`.

**class** `calendar.HTMLCalendar` (`[firstweekday]`)

This class can be used to generate HTML calendars. New in version 2.5. `HTMLCalendar` instances have the following methods:

**formatmonth** (`theyear, themonth`, `[withyear]`)

Return a month's calendar as an HTML table. If `withyear` is true the year will be included in the header, otherwise just the month name will be used.

**formatyear** (`theyear`, `[width]`)

Return a year's calendar as an HTML table. `width` (defaulting to 3) specifies the number of months per row.

**formatyearpage** (`theyear`, `[width, css, encoding]`)

Return a year's calendar as a complete HTML page. `width` (defaulting to 3) specifies the number of months per row. `css` is the name for the cascading style sheet to be used. `None` can be passed if no style sheet should be used. `encoding` specifies the encoding to be used for the output (defaulting to the system default encoding).

**class** `calendar.LocaleTextCalendar` (`[firstweekday, locale]`)

This subclass of `TextCalendar` can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode. New in version 2.5.

**class** `calendar.LocaleHTMLCalendar` (`[firstweekday, locale]`)

This subclass of `HTMLCalendar` can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode. New in version 2.5.

---

**Note:** The `formatweekday()` and `formatmonthname()` methods of these two classes temporarily change the current locale to the given `locale`. Because the current locale is a process-wide setting, they are not thread-safe.

---

For simple text calendars this module provides the following functions.

`calendar.setfirstweekday` (`weekday`)

Sets the weekday (0 is Monday, 6 is Sunday) to start each week. The values `MONDAY`, `TUESDAY`, `WEDNESDAY`,

THURSDAY, FRIDAY, SATURDAY, and SUNDAY are provided for convenience. For example, to set the first weekday to Sunday:

```
import calendar
calendar.setfirstweekday(calendar.SUNDAY)
```

New in version 2.0.

`calendar.firstweekday()`

Returns the current setting for the weekday to start each week. New in version 2.0.

`calendar.isleap(year)`

Returns `True` if `year` is a leap year, otherwise `False`.

`calendar.leapdays(y1, y2)`

Returns the number of leap years in the range from `y1` to `y2` (exclusive), where `y1` and `y2` are years. Changed in version 2.0: This function didn't work for ranges spanning a century change in Python 1.5.2.

`calendar.weekday(year, month, day)`

Returns the day of the week (0 is Monday) for `year` (1970–...), `month` (1–12), `day` (1–31).

`calendar.weekheader(n)`

Return a header containing abbreviated weekday names. `n` specifies the width in characters for one weekday.

`calendar.monthrange(year, month)`

Returns weekday of first day of the month and number of days in month, for the specified `year` and `month`.

`calendar.monthcalendar(year, month)`

Returns a matrix representing a month's calendar. Each row represents a week; days outside of the month are represented by zeros. Each week begins with Monday unless set by `setfirstweekday()`.

`calendar.prcmonth(theyear, themonth[, w[, l]])`

Prints a month's calendar as returned by `month()`.

`calendar.month(theyear, themonth[, w[, l]])`

Returns a month's calendar in a multi-line string using the `formatmonth()` of the `TextCalendar` class. New in version 2.0.

`calendar.prcal(year[, w[, l[c]]])`

Prints the calendar for an entire year as returned by `calendar()`.

`calendar.calendar(year[, w[, l[c]]])`

Returns a 3-column calendar for an entire year as a multi-line string using the `formatyear()` of the `TextCalendar` class. New in version 2.0.

`calendar.timegm(tuple)`

An unrelated but handy function that takes a time tuple such as returned by the `gmtime()` function in the `time` module, and returns the corresponding Unix timestamp value, assuming an epoch of 1970, and the POSIX encoding. In fact, `time.gmtime()` and `timegm()` are each others' inverse. New in version 2.0.

The `calendar` module exports the following data attributes:

`calendar.day_name`

An array that represents the days of the week in the current locale.

`calendar.day_abbr`

An array that represents the abbreviated days of the week in the current locale.

`calendar.month_name`

An array that represents the months of the year in the current locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_name[0]` is the empty string.

`calendar.month_abbrev`

An array that represents the abbreviated months of the year in the current locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_abbrev[0]` is the empty string.

**See Also:**

**Module `datetime`** Object-oriented interface to dates and times with similar functionality to the `time` module.

**Module `time`** Low-level time related functions.

## 8.3 collections — High-performance container datatypes

New in version 2.4. **Source code:** `Lib/collections.py` and `Lib/_abcoll.py`

This module implements specialized container datatypes providing alternatives to Python’s general purpose built-in containers, `dict`, `list`, `set`, and `tuple`.

<code>namedtuple()</code>	factory function for creating tuple subclasses with named fields	New in version 2.6.
<code>deque</code>	list-like container with fast appends and pops on either end	New in version 2.4.
<code>Counter</code>	dict subclass for counting hashable objects	New in version 2.7.
<code>OrderedDict</code>	dict subclass that remembers the order entries were added	New in version 2.7.
<code>defaultdict</code>	dict subclass that calls a factory function to supply missing values	New in version 2.5.

In addition to the concrete container classes, the collections module provides *abstract base classes* that can be used to test whether a class provides a particular interface, for example, whether it is hashable or a mapping.

### 8.3.1 Counter objects

A counter tool is provided to support convenient and rapid tallies. For example:

```
>>> # Tally occurrences of words in a list
>>> cnt = Counter()
>>> for word in ['red', 'blue', 'red', 'green', 'blue', 'blue']:
...     cnt[word] += 1
>>> cnt
Counter({'blue': 3, 'red': 2, 'green': 1})
```

```
>>> # Find the ten most common words in Hamlet
>>> import re
>>> words = re.findall('\w+', open('hamlet.txt').read().lower())
>>> Counter(words).most_common(10)
[('the', 1143), ('and', 966), ('to', 762), ('of', 669), ('i', 631),
 ('you', 554), ('a', 546), ('my', 514), ('hamlet', 471), ('in', 451)]
```

**class `collections.Counter`** (*[iterable-or-mapping]*)

A `Counter` is a `dict` subclass for counting hashable objects. It is an unordered collection where elements are stored as dictionary keys and their counts are stored as dictionary values. Counts are allowed to be any integer value including zero or negative counts. The `Counter` class is similar to bags or multisets in other languages.

Elements are counted from an *iterable* or initialized from another *mapping* (or counter):

```
>>> c = Counter() # a new, empty counter
>>> c = Counter('gallahad') # a new counter from an iterable
>>> c = Counter({'red': 4, 'blue': 2}) # a new counter from a mapping
>>> c = Counter(cats=4, dogs=8) # a new counter from keyword args
```

Counter objects have a dictionary interface except that they return a zero count for missing items instead of raising a `KeyError`:

```
>>> c = Counter(['eggs', 'ham'])
>>> c['bacon']                                # count of a missing element is zero
0
```

Setting a count to zero does not remove an element from a counter. Use `del` to remove it entirely:

```
>>> c['sausage'] = 0                          # counter entry with a zero count
>>> del c['sausage']                          # del actually removes the entry
```

New in version 2.7. Counter objects support three methods beyond those available for all dictionaries:

#### **elements()**

Return an iterator over elements repeating each as many times as its count. Elements are returned in arbitrary order. If an element's count is less than one, `elements()` will ignore it.

```
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> list(c.elements())
['a', 'a', 'a', 'a', 'b', 'b']
```

#### **most\_common([n])**

Return a list of the *n* most common elements and their counts from the most common to the least. If *n* is not specified, `most_common()` returns *all* elements in the counter. Elements with equal counts are ordered arbitrarily:

```
>>> Counter('abracadabra').most_common(3)
[('a', 5), ('r', 2), ('b', 2)]
```

#### **subtract([iterable-or-mapping])**

Elements are subtracted from an *iterable* or from another *mapping* (or counter). Like `dict.update()` but subtracts counts instead of replacing them. Both inputs and outputs may be zero or negative.

```
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> d = Counter(a=1, b=2, c=3, d=4)
>>> c.subtract(d)
Counter({'a': 3, 'b': 0, 'c': -3, 'd': -6})
```

The usual dictionary methods are available for `Counter` objects except for two which work differently for counters.

#### **fromkeys(iterable)**

This class method is not implemented for `Counter` objects.

#### **update([iterable-or-mapping])**

Elements are counted from an *iterable* or added-in from another *mapping* (or counter). Like `dict.update()` but adds counts instead of replacing them. Also, the *iterable* is expected to be a sequence of elements, not a sequence of (key, value) pairs.

Common patterns for working with `Counter` objects:

```
sum(c.values())          # total of all counts
c.clear()                # reset all counts
list(c)                  # list unique elements
set(c)                   # convert to a set
```

```
dict(c)                # convert to a regular dictionary
c.items()              # convert to a list of (elem, cnt) pairs
Counter(dict(list_of_pairs)) # convert from a list of (elem, cnt) pairs
c.most_common()[:n:-1] # n least common elements
c += Counter()         # remove zero and negative counts
```

Several mathematical operations are provided for combining `Counter` objects to produce multisets (counters that have counts greater than zero). Addition and subtraction combine counters by adding or subtracting the counts of corresponding elements. Intersection and union return the minimum and maximum of corresponding counts. Each operation can accept inputs with signed counts, but the output will exclude results with counts of zero or less.

```
>>> c = Counter(a=3, b=1)
>>> d = Counter(a=1, b=2)
>>> c + d                # add two counters together: c[x] + d[x]
Counter({'a': 4, 'b': 3})
>>> c - d                # subtract (keeping only positive counts)
Counter({'a': 2})
>>> c & d                # intersection: min(c[x], d[x])
Counter({'a': 1, 'b': 1})
>>> c | d                # union: max(c[x], d[x])
Counter({'a': 3, 'b': 2})
```

---

**Note:** Counters were primarily designed to work with positive integers to represent running counts; however, care was taken to not unnecessarily preclude use cases needing other types or negative values. To help with those use cases, this section documents the minimum range and type restrictions.

- The `Counter` class itself is a dictionary subclass with no restrictions on its keys and values. The values are intended to be numbers representing counts, but you *could* store anything in the value field.
- The `most_common()` method requires only that the values be orderable.
- For in-place operations such as `c[key] += 1`, the value type need only support addition and subtraction. So fractions, floats, and decimals would work and negative values are supported. The same is also true for `update()` and `subtract()` which allow negative and zero values for both inputs and outputs.
- The multiset methods are designed only for use cases with positive values. The inputs may be negative or zero, but only outputs with positive values are created. There are no type restrictions, but the value type needs to support addition, subtraction, and comparison.
- The `elements()` method requires integer counts. It ignores zero and negative counts.

---

### See Also:

- [Counter class](#) adapted for Python 2.5 and an early [Bag recipe](#) for Python 2.4.
- [Bag class](#) in Smalltalk.
- [Wikipedia entry for Multisets](#).
- [C++ multisets](#) tutorial with examples.
- For mathematical operations on multisets and their use cases, see *Knuth, Donald. The Art of Computer Programming Volume II, Section 4.6.3, Exercise 19*.
- To enumerate all distinct multisets of a given size over a given set of elements, see `itertools.combinations_with_replacement()`.

```
map(Counter, combinations_with_replacement('ABC', 2)) -> AA AB AC BB BC CC
```

### 8.3.2 deque objects

**class** `collections.deque` (`[iterable[, maxlen]]`)

Returns a new deque object initialized left-to-right (using `append()`) with data from *iterable*. If *iterable* is not specified, the new deque is empty.

Deques are a generalization of stacks and queues (the name is pronounced “deck” and is short for “double-ended queue”). Deques support thread-safe, memory efficient appends and pops from either side of the deque with approximately the same  $O(1)$  performance in either direction.

Though `list` objects support similar operations, they are optimized for fast fixed-length operations and incur  $O(n)$  memory movement costs for `pop(0)` and `insert(0, v)` operations which change both the size and position of the underlying data representation. New in version 2.4. If *maxlen* is not specified or is `None`, deques may grow to an arbitrary length. Otherwise, the deque is bounded to the specified maximum length. Once a bounded length deque is full, when new items are added, a corresponding number of items are discarded from the opposite end. Bounded length deques provide functionality similar to the `tail` filter in Unix. They are also useful for tracking transactions and other pools of data where only the most recent activity is of interest. Changed in version 2.6: Added *maxlen* parameter. Deque objects support the following methods:

**append** (*x*)

Add *x* to the right side of the deque.

**appendleft** (*x*)

Add *x* to the left side of the deque.

**clear** ()

Remove all elements from the deque leaving it with length 0.

**count** (*x*)

Count the number of deque elements equal to *x*. New in version 2.7.

**extend** (*iterable*)

Extend the right side of the deque by appending elements from the *iterable* argument.

**extendleft** (*iterable*)

Extend the left side of the deque by appending elements from *iterable*. Note, the series of left appends results in reversing the order of elements in the *iterable* argument.

**pop** ()

Remove and return an element from the right side of the deque. If no elements are present, raises an `IndexError`.

**popleft** ()

Remove and return an element from the left side of the deque. If no elements are present, raises an `IndexError`.

**remove** (*value*)

Removed the first occurrence of *value*. If not found, raises a `ValueError`. New in version 2.5.

**reverse** ()

Reverse the elements of the deque in-place and then return `None`. New in version 2.7.

**rotate** (*n*)

Rotate the deque *n* steps to the right. If *n* is negative, rotate to the left. Rotating one step to the right is equivalent to: `d.appendleft(d.pop())`.

Deque objects also provide one read-only attribute:

**maxlen**

Maximum size of a deque or `None` if unbounded. New in version 2.7.

In addition to the above, deques support iteration, pickling, `len(d)`, `reversed(d)`, `copy.copy(d)`, `copy.deepcopy(d)`, membership testing with the `in` operator, and subscript references such as `d[-1]`. Indexed access is  $O(1)$  at both ends but slows to  $O(n)$  in the middle. For fast random access, use lists instead.

Example:

```
>>> from collections import deque
>>> d = deque('ghi')           # make a new deque with three items
>>> for elem in d:           # iterate over the deque's elements
...     print elem.upper()
G
H
I

>>> d.append('j')            # add a new entry to the right side
>>> d.appendleft('f')        # add a new entry to the left side
>>> d                        # show the representation of the deque
deque(['f', 'g', 'h', 'i', 'j'])

>>> d.pop()                  # return and remove the rightmost item
'j'
>>> d.popleft()              # return and remove the leftmost item
'f'
>>> list(d)                  # list the contents of the deque
['g', 'h', 'i']
>>> d[0]                      # peek at leftmost item
'g'
>>> d[-1]                    # peek at rightmost item
'i'

>>> list(reversed(d))        # list the contents of a deque in reverse
['i', 'h', 'g']
>>> 'h' in d                  # search the deque
True
>>> d.extend('jkl')          # add multiple elements at once
>>> d
deque(['g', 'h', 'i', 'j', 'k', 'l'])
>>> d.rotate(1)              # right rotation
>>> d
deque(['l', 'g', 'h', 'i', 'j', 'k'])
>>> d.rotate(-1)             # left rotation
>>> d
deque(['g', 'h', 'i', 'j', 'k', 'l'])

>>> deque(reversed(d))        # make a new deque in reverse order
deque(['l', 'k', 'j', 'i', 'h', 'g'])
>>> d.clear()                 # empty the deque
>>> d.pop()                   # cannot pop from an empty deque
Traceback (most recent call last):
  File "<pyshell#6>", line 1, in -toplevel-
    d.pop()
IndexError: pop from an empty deque

>>> d.extendleft('abc')      # extendleft() reverses the input order
>>> d
```

```
deque(['c', 'b', 'a'])
```

## deque Recipes

This section shows various approaches to working with deques.

Bounded length deques provide functionality similar to the `tail` filter in Unix:

```
def tail(filename, n=10):
    'Return the last n lines of a file'
    return deque(open(filename), n)
```

Another approach to using deques is to maintain a sequence of recently added elements by appending to the right and popping to the left:

```
def moving_average(iterable, n=3):
    # moving_average([40, 30, 50, 46, 39, 44]) --> 40.0 42.0 45.0 43.0
    # http://en.wikipedia.org/wiki/Moving_average
    it = iter(iterable)
    d = deque(itertools.islice(it, n-1))
    d.appendleft(0)
    s = sum(d)
    for elem in it:
        s += elem - d.popleft()
        d.append(elem)
        yield s / float(n)
```

The `rotate()` method provides a way to implement `deque` slicing and deletion. For example, a pure Python implementation of `del d[n]` relies on the `rotate()` method to position elements to be popped:

```
def delete_nth(d, n):
    d.rotate(-n)
    d.popleft()
    d.rotate(n)
```

To implement `deque` slicing, use a similar approach applying `rotate()` to bring a target element to the left side of the deque. Remove old entries with `popleft()`, add new entries with `extend()`, and then reverse the rotation. With minor variations on that approach, it is easy to implement Forth style stack manipulations such as `dup`, `drop`, `swap`, `over`, `pick`, `rot`, and `roll`.

### 8.3.3 defaultdict objects

```
class collections.defaultdict ([default_factory[, ... ]])
```

Returns a new dictionary-like object. `defaultdict` is a subclass of the built-in `dict` class. It overrides one method and adds one writable instance variable. The remaining functionality is the same as for the `dict` class and is not documented here.

The first argument provides the initial value for the `default_factory` attribute; it defaults to `None`. All remaining arguments are treated the same as if they were passed to the `dict` constructor, including keyword arguments. New in version 2.5. `defaultdict` objects support the following method in addition to the standard `dict` operations:

```
__missing__(key)
```

If the `default_factory` attribute is `None`, this raises a `KeyError` exception with the `key` as argument.

If `default_factory` is not `None`, it is called without arguments to provide a default value for the given `key`, this value is inserted in the dictionary for the `key`, and returned.

If calling `default_factory` raises an exception this exception is propagated unchanged.

This method is called by the `__getitem__()` method of the `dict` class when the requested key is not found; whatever it returns or raises is then returned or raised by `__getitem__()`.

Note that `__missing__()` is *not* called for any operations besides `__getitem__()`. This means that `get()` will, like normal dictionaries, return `None` as a default rather than using `default_factory`.

`defaultdict` objects support the following instance variable:

#### **default\_factory**

This attribute is used by the `__missing__()` method; it is initialized from the first argument to the constructor, if present, or to `None`, if absent.

### **defaultdict Examples**

Using `list` as the `default_factory`, it is easy to group a sequence of key-value pairs into a dictionary of lists:

```
>>> s = [('yellow', 1), ('blue', 2), ('yellow', 3), ('blue', 4), ('red', 1)]
>>> d = defaultdict(list)
>>> for k, v in s:
...     d[k].append(v)
...
>>> d.items()
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

When each key is encountered for the first time, it is not already in the mapping; so an entry is automatically created using the `default_factory` function which returns an empty `list`. The `list.append()` operation then attaches the value to the new list. When keys are encountered again, the look-up proceeds normally (returning the list for that key) and the `list.append()` operation adds another value to the list. This technique is simpler and faster than an equivalent technique using `dict.setdefault()`:

```
>>> d = {}
>>> for k, v in s:
...     d.setdefault(k, []).append(v)
...
>>> d.items()
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

Setting the `default_factory` to `int` makes the `defaultdict` useful for counting (like a bag or multiset in other languages):

```
>>> s = 'mississippi'
>>> d = defaultdict(int)
>>> for k in s:
...     d[k] += 1
...
>>> d.items()
[('i', 4), ('p', 2), ('s', 4), ('m', 1)]
```

When a letter is first encountered, it is missing from the mapping, so the `default_factory` function calls `int()` to supply a default count of zero. The increment operation then builds up the count for each letter.

The function `int()` which always returns zero is just a special case of constant functions. A faster and more flexible way to create constant functions is to use `itertools.repeat()` which can supply any constant value (not just zero):

```
>>> def constant_factory(value):
...     return itertools.repeat(value).next
>>> d = defaultdict(constant_factory('<missing>'))
>>> d.update(name='John', action='ran')
>>> '%(name)s %(action)s to %(object)s' % d
'John ran to <missing>'
```

Setting the `default_factory` to `set` makes the `defaultdict` useful for building a dictionary of sets:

```
>>> s = [('red', 1), ('blue', 2), ('red', 3), ('blue', 4), ('red', 1), ('blue', 4)]
>>> d = defaultdict(set)
>>> for k, v in s:
...     d[k].add(v)
...
>>> d.items()
[('blue', set([2, 4])), ('red', set([1, 3]))]
```

### 8.3.4 `namedtuple()` Factory Function for Tuples with Named Fields

Named tuples assign meaning to each position in a tuple and allow for more readable, self-documenting code. They can be used wherever regular tuples are used, and they add the ability to access fields by name instead of position index.

`collections.namedtuple` (*typename*, *field\_names* [, *verbose=False*] [, *rename=False* ])

Returns a new tuple subclass named *typename*. The new subclass is used to create tuple-like objects that have fields accessible by attribute lookup as well as being indexable and iterable. Instances of the subclass also have a helpful docstring (with *typename* and *field\_names*) and a helpful `__repr__()` method which lists the tuple contents in a `name=value` format.

The *field\_names* are a sequence of strings such as `['x', 'y']`. Alternatively, *field\_names* can be a single string with each fieldname separated by whitespace and/or commas, for example `'x y'` or `'x, y'`.

Any valid Python identifier may be used for a fieldname except for names starting with an underscore. Valid identifiers consist of letters, digits, and underscores but do not start with a digit or underscore and cannot be a *keyword* such as `class`, `for`, `return`, `global`, `pass`, `print`, or `raise`.

If *rename* is true, invalid fieldnames are automatically replaced with positional names. For example, `['abc', 'def', 'ghi', 'abc']` is converted to `['abc', '_1', 'ghi', '_3']`, eliminating the keyword `def` and the duplicate fieldname `abc`.

If *verbose* is true, the class definition is printed just before being built.

Named tuple instances do not have per-instance dictionaries, so they are lightweight and require no more memory than regular tuples. New in version 2.6. Changed in version 2.7: added support for *rename*.

Example:

```
>>> Point = namedtuple('Point', ['x', 'y'], verbose=True)
class Point(tuple):
    'Point(x, y)'

    __slots__ = ()

    _fields = ('x', 'y')

    def __new__(_cls, x, y):
        'Create a new instance of Point(x, y)'
        return _tuple.__new__(_cls, (x, y))
```

```

@classmethod
def _make(cls, iterable, new=tuple.__new__, len=len):
    'Make a new Point object from a sequence or iterable'
    result = new(cls, iterable)
    if len(result) != 2:
        raise TypeError('Expected 2 arguments, got %d' % len(result))
    return result

def __repr__(self):
    'Return a nicely formatted representation string'
    return 'Point(x=%r, y=%r)' % self

def _asdict(self):
    'Return a new OrderedDict which maps field names to their values'
    return OrderedDict(zip(self._fields, self))

__dict__ = property(_asdict)

def _replace(_self, **kws):
    'Return a new Point object replacing specified fields with new values'
    result = _self._make(map(kws.pop, ('x', 'y'), _self))
    if kws:
        raise ValueError('Got unexpected field names: %r' % kws.keys())
    return result

def __getnewargs__(self):
    'Return self as a plain tuple.  Used by copy and pickle.'
    return tuple(self)

x = _property(_itemgetter(0), doc='Alias for field number 0')
y = _property(_itemgetter(1), doc='Alias for field number 1')

```

```

>>> p = Point(11, y=22)      # instantiate with positional or keyword arguments
>>> p[0] + p[1]             # indexable like the plain tuple (11, 22)
33
>>> x, y = p                # unpack like a regular tuple
>>> x, y
(11, 22)
>>> p.x + p.y               # fields also accessible by name
33
>>> p                       # readable __repr__ with a name=value style
Point(x=11, y=22)

```

Named tuples are especially useful for assigning field names to result tuples returned by the `csv` or `sqlite3` modules:

```

EmployeeRecord = namedtuple('EmployeeRecord', 'name, age, title, department, paygrade')

import csv
for emp in map(EmployeeRecord._make, csv.reader(open("employees.csv", "rb"))):
    print emp.name, emp.title

```

```
import sqlite3
conn = sqlite3.connect('/companydata')
cursor = conn.cursor()
cursor.execute('SELECT name, age, title, department, paygrade FROM employees')
for emp in map(EmployeeRecord._make, cursor.fetchall()):
    print emp.name, emp.title
```

In addition to the methods inherited from tuples, named tuples support three additional methods and one attribute. To prevent conflicts with field names, the method and attribute names start with an underscore.

**classmethod** `somenamedtuple._make` (*iterable*)

Class method that makes a new instance from an existing sequence or iterable.

```
>>> t = [11, 22]
>>> Point._make(t)
Point(x=11, y=22)
```

`somenamedtuple._asdict` ()

Return a new `OrderedDict` which maps field names to their corresponding values:

```
>>> p._asdict()
OrderedDict([('x', 11), ('y', 22)])
```

Changed in version 2.7: Returns an `OrderedDict` instead of a regular `dict`.

`somenamedtuple._replace` (*kwargs*)

Return a new instance of the named tuple replacing specified fields with new values:

```
>>> p = Point(x=11, y=22)
>>> p._replace(x=33)
Point(x=33, y=22)

>>> for partnum, record in inventory.items():
    inventory[partnum] = record._replace(price=newprices[partnum], timestamp=time.)
```

`somenamedtuple._fields`

Tuple of strings listing the field names. Useful for introspection and for creating new named tuple types from existing named tuples.

```
>>> p._fields           # view the field names
('x', 'y')

>>> Color = namedtuple('Color', 'red green blue')
>>> Pixel = namedtuple('Pixel', Point._fields + Color._fields)
>>> Pixel(11, 22, 128, 255, 0)
Pixel(x=11, y=22, red=128, green=255, blue=0)
```

To retrieve a field whose name is stored in a string, use the `getattr()` function:

```
>>> getattr(p, 'x')
11
```

To convert a dictionary to a named tuple, use the double-star-operator (as described in *tut-unpacking-arguments*):

```
>>> d = {'x': 11, 'y': 22}
>>> Point(**d)
Point(x=11, y=22)
```

Since a named tuple is a regular Python class, it is easy to add or change functionality with a subclass. Here is how to add a calculated field and a fixed-width print format:

```
>>> class Point(namedtuple('Point', 'x y')):
    __slots__ = ()
    @property
    def hypot(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5
    def __str__(self):
        return 'Point: x=%6.3f y=%6.3f hypot=%6.3f' % (self.x, self.y, self.hypot)

>>> for p in Point(3, 4), Point(14, 5/7.):
    print p
Point: x= 3.000 y= 4.000 hypot= 5.000
Point: x=14.000 y= 0.714 hypot=14.018
```

The subclass shown above sets `__slots__` to an empty tuple. This helps keep memory requirements low by preventing the creation of instance dictionaries.

Subclassing is not useful for adding new, stored fields. Instead, simply create a new named tuple type from the `_fields` attribute:

```
>>> Point3D = namedtuple('Point3D', Point._fields + ('z',))
```

Default values can be implemented by using `_replace()` to customize a prototype instance:

```
>>> Account = namedtuple('Account', 'owner balance transaction_count')
>>> default_account = Account('<owner name>', 0.0, 0)
>>> johns_account = default_account._replace(owner='John')
```

Enumerated constants can be implemented with named tuples, but it is simpler and more efficient to use a simple class declaration:

```
>>> Status = namedtuple('Status', 'open pending closed')._make(range(3))
>>> Status.open, Status.pending, Status.closed
(0, 1, 2)
>>> class Status:
    open, pending, closed = range(3)
```

### See Also:

[Named tuple recipe](#) adapted for Python 2.4.

## 8.3.5 OrderedDict objects

Ordered dictionaries are just like regular dictionaries but they remember the order that items were inserted. When iterating over an ordered dictionary, the items are returned in the order their keys were first added.

```
class collections.OrderedDict([items])
```

Return an instance of a dict subclass, supporting the usual `dict` methods. An *OrderedDict* is a dict that remembers the order that keys were first inserted. If a new entry overwrites an existing entry, the original insertion position is left unchanged. Deleting an entry and reinserting it will move it to the end. New in version 2.7.

`OrderedDict.popitem(last=True)`

The `popitem()` method for ordered dictionaries returns and removes a (key, value) pair. The pairs are returned in LIFO order if *last* is true or FIFO order if false.

In addition to the usual mapping methods, ordered dictionaries also support reverse iteration using `reversed()`.

Equality tests between `OrderedDict` objects are order-sensitive and are implemented as `list(od1.items())==list(od2.items())`. Equality tests between `OrderedDict` objects and other `Mapping` objects are order-insensitive like regular dictionaries. This allows `OrderedDict` objects to be substituted anywhere a regular dictionary is used.

The `OrderedDict` constructor and `update()` method both accept keyword arguments, but their order is lost because Python's function call semantics pass-in keyword arguments using a regular unordered dictionary.

#### See Also:

Equivalent `OrderedDict` recipe that runs on Python 2.4 or later.

### OrderedDict Examples and Recipes

Since an ordered dictionary remembers its insertion order, it can be used in conjunction with sorting to make a sorted dictionary:

```
>>> # regular unsorted dictionary
>>> d = {'banana': 3, 'apple': 4, 'pear': 1, 'orange': 2}

>>> # dictionary sorted by key
>>> OrderedDict(sorted(d.items(), key=lambda t: t[0]))
OrderedDict([('apple', 4), ('banana', 3), ('orange', 2), ('pear', 1)])

>>> # dictionary sorted by value
>>> OrderedDict(sorted(d.items(), key=lambda t: t[1]))
OrderedDict([('pear', 1), ('orange', 2), ('banana', 3), ('apple', 4)])

>>> # dictionary sorted by length of the key string
>>> OrderedDict(sorted(d.items(), key=lambda t: len(t[0])))
OrderedDict([('pear', 1), ('apple', 4), ('orange', 2), ('banana', 3)])
```

The new sorted dictionaries maintain their sort order when entries are deleted. But when new keys are added, the keys are appended to the end and the sort is not maintained.

It is also straight-forward to create an ordered dictionary variant that remembers the order the keys were *last* inserted. If a new entry overwrites an existing entry, the original insertion position is changed and moved to the end:

```
class LastUpdatedOrderedDict(OrderedDict):
    'Store items in the order the keys were last added'

    def __setitem__(self, key, value):
        if key in self:
            del self[key]
        OrderedDict.__setitem__(self, key, value)
```

An ordered dictionary can be combined with the `Counter` class so that the counter remembers the order elements are first encountered:

```
class OrderedCounter(Counter, OrderedDict):
    'Counter that remembers the order elements are first encountered'

    def __repr__(self):
        return '%s(%r)' % (self.__class__.__name__, OrderedDict(self))

    def __reduce__(self):
        return self.__class__, (OrderedDict(self),)
```

### 8.3.6 Collections Abstract Base Classes

The collections module offers the following *ABCs*:

ABC	Inherits from	Abstract Methods	Mixin Methods
Container		<code>__contains__</code>	
Hashable		<code>__hash__</code>	
Iterable		<code>__iter__</code>	
Iterator	Iterable	<code>next</code>	<code>__iter__</code>
Sized		<code>__len__</code>	
Callable		<code>__call__</code>	
Sequence	Sized, Iterable, Container	<code>__getitem__</code>	<code>__contains__</code> , <code>__iter__</code> , <code>__reversed__</code> , index, and count
MutableSequence	Sequence	<code>__setitem__</code> , <code>__delitem__</code> , insert	Inherited <a href="#">Sequence</a> methods and <code>append</code> , <code>reverse</code> , <code>extend</code> , <code>pop</code> , <code>remove</code> , and <code>__iadd__</code>
Set	Sized, Iterable, Container		<code>__le__</code> , <code>__lt__</code> , <code>__eq__</code> , <code>__ne__</code> , <code>__gt__</code> , <code>__ge__</code> , <code>__and__</code> , <code>__or__</code> , <code>__sub__</code> , <code>__xor__</code> , and <code>isdisjoint</code>
MutableSet	Set	<code>add</code> , <code>discard</code>	Inherited <a href="#">Set</a> methods and <code>clear</code> , <code>pop</code> , <code>remove</code> , <code>__ior__</code> , <code>__iand__</code> , <code>__ixor__</code> , and <code>__isub__</code>
Mapping	Sized, Iterable, Container	<code>__getitem__</code>	<code>__contains__</code> , <code>keys</code> , <code>items</code> , <code>values</code> , <code>get</code> , <code>__eq__</code> , and <code>__ne__</code>
MutableMapping	Mapping	<code>__setitem__</code> , <code>__delitem__</code>	Inherited <a href="#">Mapping</a> methods and <code>pop</code> , <code>popitem</code> , <code>clear</code> , <code>update</code> , and <code>setdefault</code>
MappingView	Sized		<code>__len__</code>
ItemsView	MappingView, Set		<code>__contains__</code> , <code>__iter__</code>
KeysView	MappingView, Set		<code>__contains__</code> , <code>__iter__</code>
ValuesView	MappingView		<code>__contains__</code> , <code>__iter__</code>

**class** `collections.Container`

**class** `collections.Hashable`

**class** `collections.Sized`

**class** `collections.Callable`

ABCs for classes that provide respectively the methods `__contains__()`, `__hash__()`, `__len__()`, and `__call__()`.

**class** `collections.Iterable`

ABC for classes that provide the `__iter__()` method. See also the definition of *iterable*.

**class** `collections.Iterator`

ABC for classes that provide the `__iter__()` and `next()` methods. See also the definition of *iterator*.

**class** `collections.Sequence`

**class** `collections.MutableSequence`

ABCs for read-only and mutable *sequences*.

**class** `collections.Set`

**class** `collections.MutableSet`

ABCs for read-only and mutable sets.

**class** `collections.Mapping`

```
class collections.MutableMapping
    ABCs for read-only and mutable mappings.
```

```
class collections.MappingView
```

```
class collections.ItemsView
```

```
class collections.KeysView
```

```
class collections.ValuesView
```

ABCs for mapping, items, keys, and values *views*.

These ABCs allow us to ask classes or instances if they provide particular functionality, for example:

```
size = None
if isinstance(myvar, collections.Sized):
    size = len(myvar)
```

Several of the ABCs are also useful as mixins that make it easier to develop classes supporting container APIs. For example, to write a class supporting the full `Set` API, it only necessary to supply the three underlying abstract methods: `__contains__()`, `__iter__()`, and `__len__()`. The ABC supplies the remaining methods such as `__and__()` and `isdisjoint()`

```
class ListBasedSet(collections.Set):
    ''' Alternate set implementation favoring space over speed
        and not requiring the set elements to be hashable. '''
    def __init__(self, iterable):
        self.elements = lst = []
        for value in iterable:
            if value not in lst:
                lst.append(value)
    def __iter__(self):
        return iter(self.elements)
    def __contains__(self, value):
        return value in self.elements
    def __len__(self):
        return len(self.elements)
```

```
s1 = ListBasedSet('abcdef')
s2 = ListBasedSet('defghi')
overlap = s1 & s2           # The __and__() method is supported automatically
```

Notes on using `Set` and `MutableSet` as a mixin:

1. Since some set operations create new sets, the default mixin methods need a way to create new instances from an iterable. The class constructor is assumed to have a signature in the form `ClassName(iterable)`. That assumption is factored-out to an internal classmethod called `_from_iterable()` which calls `cls(iterable)` to produce a new set. If the `Set` mixin is being used in a class with a different constructor signature, you will need to override `_from_iterable()` with a classmethod that can construct new instances from an iterable argument.
2. To override the comparisons (presumably for speed, as the semantics are fixed), redefine `__le__()` and then the other operations will automatically follow suit.
3. The `Set` mixin provides a `_hash()` method to compute a hash value for the set; however, `__hash__()` is not defined because not all sets are hashable or immutable. To add set hashability using mixins, inherit from both `Set()` and `Hashable()`, then define `__hash__ = Set._hash`.

**See Also:**

- [OrderedSet recipe](#) for an example built on `MutableSet`.
- For more about ABCs, see the `abc` module and [PEP 3119](#).

## 8.4 `heapq` — Heap queue algorithm

New in version 2.3. **Source code:** [Lib/heapq.py](#)

---

This module provides an implementation of the heap queue algorithm, also known as the priority queue algorithm.

Heaps are binary trees for which every parent node has a value less than or equal to any of its children. This implementation uses arrays for which `heap[k] <= heap[2*k+1]` and `heap[k] <= heap[2*k+2]` for all  $k$ , counting elements from zero. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that its smallest element is always the root, `heap[0]`.

The API below differs from textbook heap algorithms in two aspects: (a) We use zero-based indexing. This makes the relationship between the index for a node and the indexes for its children slightly less obvious, but is more suitable since Python uses zero-based indexing. (b) Our `pop` method returns the smallest item, not the largest (called a “min heap” in textbooks; a “max heap” is more common in texts because of its suitability for in-place sorting).

These two make it possible to view the heap as a regular Python list without surprises: `heap[0]` is the smallest item, and `heap.sort()` maintains the heap invariant!

To create a heap, use a list initialized to `[]`, or you can transform a populated list into a heap via function `heapify()`.

The following functions are provided:

`heapq.heappush(heap, item)`

Push the value *item* onto the *heap*, maintaining the heap invariant.

`heapq.heappop(heap)`

Pop and return the smallest item from the *heap*, maintaining the heap invariant. If the heap is empty, `IndexError` is raised.

`heapq.heappushpop(heap, item)`

Push *item* on the heap, then pop and return the smallest item from the *heap*. The combined action runs more efficiently than `heappush()` followed by a separate call to `heappop()`. New in version 2.6.

`heapq.heapify(x)`

Transform list *x* into a heap, in-place, in linear time.

`heapq.heapreplace(heap, item)`

Pop and return the smallest item from the *heap*, and also push the new *item*. The heap size doesn't change. If the heap is empty, `IndexError` is raised.

This one step operation is more efficient than a `heappop()` followed by `heappush()` and can be more appropriate when using a fixed-size heap. The pop/push combination always returns an element from the heap and replaces it with *item*.

The value returned may be larger than the *item* added. If that isn't desired, consider using `heappushpop()` instead. Its push/pop combination returns the smaller of the two values, leaving the larger value on the heap.

The module also offers three general purpose functions based on heaps.

`heapq.merge(*iterables)`

Merge multiple sorted inputs into a single sorted output (for example, merge timestamped entries from multiple log files). Returns an *iterator* over the sorted values.

Similar to `sorted(itertools.chain(*iterables))` but returns an iterable, does not pull the data into memory all at once, and assumes that each of the input streams is already sorted (smallest to largest). New in version 2.6.

`heapq.nlargest(n, iterable[, key])`

Return a list with the  $n$  largest elements from the dataset defined by *iterable*. *key*, if provided, specifies a function

of one argument that is used to extract a comparison key from each element in the iterable: `key=str.lower`  
 Equivalent to: `sorted(iterable, key=key, reverse=True) [:n]` New in version 2.4.Changed in version 2.5: Added the optional `key` argument.

`heapq.nsmallest(n, iterable[, key])`

Return a list with the *n* smallest elements from the dataset defined by *iterable*. *key*, if provided, specifies a function of one argument that is used to extract a comparison key from each element in the iterable: `key=str.lower` Equivalent to: `sorted(iterable, key=key) [:n]` New in version 2.4.Changed in version 2.5: Added the optional `key` argument.

The latter two functions perform best for smaller values of *n*. For larger values, it is more efficient to use the `sorted()` function. Also, when *n*=1, it is more efficient to use the built-in `min()` and `max()` functions.

## 8.4.1 Basic Examples

A `heapsort` can be implemented by pushing all values onto a heap and then popping off the smallest values one at a time:

```
>>> def heapsort(iterable):
...     'Equivalent to sorted(iterable)'
...     h = []
...     for value in iterable:
...         heappush(h, value)
...     return [heappop(h) for i in range(len(h))]
...
>>> heapsort([1, 3, 5, 7, 9, 2, 4, 6, 8, 0])
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

Heap elements can be tuples. This is useful for assigning comparison values (such as task priorities) alongside the main record being tracked:

```
>>> h = []
>>> heappush(h, (5, 'write code'))
>>> heappush(h, (7, 'release product'))
>>> heappush(h, (1, 'write spec'))
>>> heappush(h, (3, 'create tests'))
>>> heappop(h)
(1, 'write spec')
```

## 8.4.2 Priority Queue Implementation Notes

A `priority queue` is common use for a heap, and it presents several implementation challenges:

- Sort stability: how do you get two tasks with equal priorities to be returned in the order they were originally added?
- In the future with Python 3, tuple comparison breaks for (priority, task) pairs if the priorities are equal and the tasks do not have a default comparison order.
- If the priority of a task changes, how do you move it to a new position in the heap?
- Or if a pending task needs to be deleted, how do you find it and remove it from the queue?

A solution to the first two challenges is to store entries as 3-element list including the priority, an entry count, and the task. The entry count serves as a tie-breaker so that two tasks with the same priority are returned in the order they were added. And since no two entry counts are the same, the tuple comparison will never attempt to directly compare two tasks.

The remaining challenges revolve around finding a pending task and making changes to its priority or removing it entirely. Finding a task can be done with a dictionary pointing to an entry in the queue.

Removing the entry or changing its priority is more difficult because it would break the heap structure invariants. So, a possible solution is to mark the existing entry as removed and add a new entry with the revised priority:

```

pq = []                                # list of entries arranged in a heap
entry_finder = {}                       # mapping of tasks to entries
REMOVED = '<removed-task>'             # placeholder for a removed task
counter = itertools.count()             # unique sequence count

def add_task(task, priority=0):
    'Add a new task or update the priority of an existing task'
    if task in entry_finder:
        remove_task(task)
    count = next(counter)
    entry = [priority, count, task]
    entry_finder[task] = entry
    heappush(pq, entry)

def remove_task(task):
    'Mark an existing task as REMOVED. Raise KeyError if not found.'
    entry = entry_finder.pop(task)
    entry[-1] = REMOVED

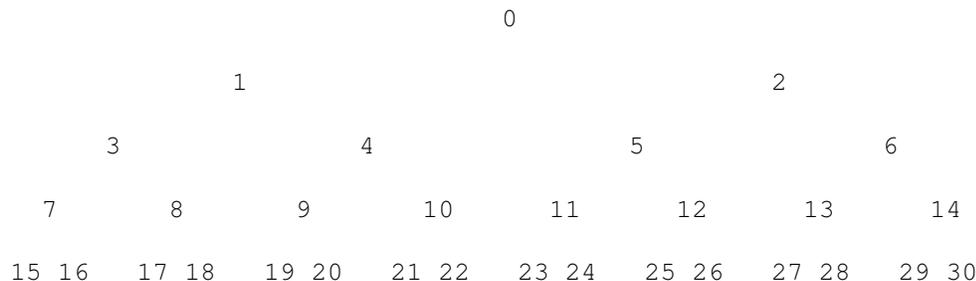
def pop_task():
    'Remove and return the lowest priority task. Raise KeyError if empty.'
    while pq:
        priority, count, task = heappop(pq)
        if task is not REMOVED:
            del entry_finder[task]
            return task
    raise KeyError('pop from an empty priority queue')

```

### 8.4.3 Theory

Heaps are arrays for which  $a[k] \leq a[2*k+1]$  and  $a[k] \leq a[2*k+2]$  for all  $k$ , counting elements from 0. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that  $a[0]$  is always its smallest element.

The strange invariant above is meant to be an efficient memory representation for a tournament. The numbers below are  $k$ , not  $a[k]$ :



In the tree above, each cell  $k$  is topping  $2*k+1$  and  $2*k+2$ . In an usual binary tournament we see in sports, each cell is the winner over the two cells it tops, and we can trace the winner down the tree to see all opponents s/he had. However, in many computer applications of such tournaments, we do not need to trace the history of a winner. To be

more memory efficient, when a winner is promoted, we try to replace it by something else at a lower level, and the rule becomes that a cell and the two cells it tops contain three different items, but the top cell “wins” over the two topped cells.

If this heap invariant is protected at all time, index 0 is clearly the overall winner. The simplest algorithmic way to remove it and find the “next” winner is to move some loser (let’s say cell 30 in the diagram above) into the 0 position, and then percolate this new 0 down the tree, exchanging values, until the invariant is re-established. This is clearly logarithmic on the total number of items in the tree. By iterating over all items, you get an  $O(n \log n)$  sort.

A nice feature of this sort is that you can efficiently insert new items while the sort is going on, provided that the inserted items are not “better” than the last 0’th element you extracted. This is especially useful in simulation contexts, where the tree holds all incoming events, and the “win” condition means the smallest scheduled time. When an event schedule other events for execution, they are scheduled into the future, so they can easily go into the heap. So, a heap is a good structure for implementing schedulers (this is what I used for my MIDI sequencer :-).

Various structures for implementing schedulers have been extensively studied, and heaps are good for this, as they are reasonably speedy, the speed is almost constant, and the worst case is not much different than the average case. However, there are other representations which are more efficient overall, yet the worst cases might be terrible.

Heaps are also very useful in big disk sorts. You most probably all know that a big sort implies producing “runs” (which are pre-sorted sequences, which size is usually related to the amount of CPU memory), followed by a merging passes for these runs, which merging is often very cleverly organised<sup>2</sup>. It is very important that the initial sort produces the longest runs possible. Tournaments are a good way to that. If, using all the memory available to hold a tournament, you replace and percolate items that happen to fit the current run, you’ll produce runs which are twice the size of the memory for random input, and much better for input fuzzily ordered.

Moreover, if you output the 0’th item on disk and get an input which may not fit in the current tournament (because the value “wins” over the last output value), it cannot fit in the heap, so the size of the heap decreases. The freed memory could be cleverly reused immediately for progressively building a second heap, which grows at exactly the same rate the first heap is melting. When the first heap completely vanishes, you switch heaps and start a new run. Clever and quite effective!

In a word, heaps are useful memory structures to know. I use them in a few applications, and I think it is good to keep a ‘heap’ module around. :-)

## 8.5 bisect — Array bisection algorithm

New in version 2.1. **Source code:** [Lib/bisect.py](#)

This module provides support for maintaining a list in sorted order without having to sort the list after each insertion. For long lists of items with expensive comparison operations, this can be an improvement over the more common approach. The module is called `bisect` because it uses a basic bisection algorithm to do its work. The source code may be most useful as a working example of the algorithm (the boundary conditions are already right!).

The following functions are provided:

`bisect.bisect_left(a, x, lo=0, hi=len(a))`

Locate the insertion point for `x` in `a` to maintain sorted order. The parameters `lo` and `hi` may be used to specify a subset of the list which should be considered; by default the entire list is used. If `x` is already present in `a`, the insertion point will be before (to the left of) any existing entries. The return value is suitable for use as the first parameter to `list.insert()` assuming that `a` is already sorted.

<sup>2</sup> The disk balancing algorithms which are current, nowadays, are more annoying than clever, and this is a consequence of the seeking capabilities of the disks. On devices which cannot seek, like big tape drives, the story was quite different, and one had to be very clever to ensure (far in advance) that each tape movement will be the most effective possible (that is, will best participate at “progressing” the merge). Some tapes were even able to read backwards, and this was also used to avoid the rewinding time. Believe me, real good tape sorts were quite spectacular to watch! From all times, sorting has always been a Great Art! :-)

The returned insertion point  $i$  partitions the array  $a$  into two halves so that `all(val < x for val in a[lo:i])` for the left side and `all(val >= x for val in a[i:hi])` for the right side.

```
bisect.bisect_right(a, x, lo=0, hi=len(a))
```

```
bisect.bisect(a, x, lo=0, hi=len(a))
```

Similar to `bisect_left()`, but returns an insertion point which comes after (to the right of) any existing entries of  $x$  in  $a$ .

The returned insertion point  $i$  partitions the array  $a$  into two halves so that `all(val <= x for val in a[lo:i])` for the left side and `all(val > x for val in a[i:hi])` for the right side.

```
bisect.insort_left(a, x, lo=0, hi=len(a))
```

Insert  $x$  in  $a$  in sorted order. This is equivalent to `a.insert(bisect.bisect_left(a, x, lo, hi), x)` assuming that  $a$  is already sorted. Keep in mind that the  $O(\log n)$  search is dominated by the slow  $O(n)$  insertion step.

```
bisect.insort_right(a, x, lo=0, hi=len(a))
```

```
bisect.insort(a, x, lo=0, hi=len(a))
```

Similar to `insort_left()`, but inserting  $x$  in  $a$  after any existing entries of  $x$ .

#### See Also:

[SortedCollection recipe](#) that uses `bisect` to build a full-featured collection class with straight-forward search methods and support for a key-function. The keys are precomputed to save unnecessary calls to the key function during searches.

## 8.5.1 Searching Sorted Lists

The above `bisect()` functions are useful for finding insertion points but can be tricky or awkward to use for common searching tasks. The following five functions show how to transform them into the standard lookups for sorted lists:

```
def index(a, x):
    'Locate the leftmost value exactly equal to x'
    i = bisect_left(a, x)
    if i != len(a) and a[i] == x:
        return i
    raise ValueError

def find_lt(a, x):
    'Find rightmost value less than x'
    i = bisect_left(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_le(a, x):
    'Find rightmost value less than or equal to x'
    i = bisect_right(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_gt(a, x):
    'Find leftmost value greater than x'
    i = bisect_right(a, x)
    if i != len(a):
        return a[i]
    raise ValueError
```

```
def find_ge(a, x):
    'Find leftmost item greater than or equal to x'
    i = bisect_left(a, x)
    if i != len(a):
        return a[i]
    raise ValueError
```

## 8.5.2 Other Examples

The `bisect()` function can be useful for numeric table lookups. This example uses `bisect()` to look up a letter grade for an exam score (say) based on a set of ordered numeric breakpoints: 90 and up is an 'A', 80 to 89 is a 'B', and so on:

```
>>> def grade(score, breakpoints=[60, 70, 80, 90], grades='FDCBA'):
    i = bisect(breakpoints, score)
    return grades[i]
```

```
>>> [grade(score) for score in [33, 99, 77, 70, 89, 90, 100]]
['F', 'A', 'C', 'C', 'B', 'A', 'A']
```

Unlike the `sorted()` function, it does not make sense for the `bisect()` functions to have *key* or *reversed* arguments because that would lead to an inefficient design (successive calls to `bisect` functions would not “remember” all of the previous key lookups).

Instead, it is better to search a list of precomputed keys to find the index of the record in question:

```
>>> data = [('red', 5), ('blue', 1), ('yellow', 8), ('black', 0)]
>>> data.sort(key=lambda r: r[1])
>>> keys = [r[1] for r in data]           # precomputed list of keys
>>> data[bisect_left(keys, 0)]
('black', 0)
>>> data[bisect_left(keys, 1)]
('blue', 1)
>>> data[bisect_left(keys, 5)]
('red', 5)
>>> data[bisect_left(keys, 8)]
('yellow', 8)
```

## 8.6 array — Efficient arrays of numeric values

This module defines an object type which can compactly represent an array of basic values: characters, integers, floating point numbers. Arrays are sequence types and behave very much like lists, except that the type of objects stored in them is constrained. The type is specified at object creation time by using a *type code*, which is a single character. The following type codes are defined:

Type code	C Type	Python Type	Minimum size in bytes
'c'	char	character	1
'b'	signed char	int	1
'B'	unsigned char	int	1
'u'	Py_UNICODE	Unicode character	2 (see note)
'h'	signed short	int	2
'H'	unsigned short	int	2
'i'	signed int	int	2
'I'	unsigned int	long	2
'l'	signed long	int	4
'L'	unsigned long	long	4
'f'	float	float	4
'd'	double	float	8

**Note:** The 'u' typecode corresponds to Python's unicode character. On narrow Unicode builds this is 2-bytes, on wide builds this is 4-bytes.

---

The actual representation of values is determined by the machine architecture (strictly speaking, by the C implementation). The actual size can be accessed through the `itemsize` attribute. The values stored for 'L' and 'I' items will be represented as Python long integers when retrieved, because Python's plain integer type cannot represent the full range of C's unsigned (long) integers.

The module defines the following type:

**class** `array.array` (*typecode* [, *initializer* ])

A new array whose items are restricted by *typecode*, and initialized from the optional *initializer* value, which must be a list, string, or iterable over elements of the appropriate type. Changed in version 2.4: Formerly, only lists or strings were accepted. If given a list or string, the initializer is passed to the new array's `fromlist()`, `fromstring()`, or `fromunicode()` method (see below) to add initial items to the array. Otherwise, the iterable initializer is passed to the `extend()` method.

`array.ArrayType`

Obsolete alias for `array`.

Array objects support the ordinary sequence operations of indexing, slicing, concatenation, and multiplication. When using slice assignment, the assigned value must be an array object with the same type code; in all other cases, `TypeError` is raised. Array objects also implement the buffer interface, and may be used wherever buffer objects are supported.

The following data items and methods are also supported:

`array.typecode`

The typecode character used to create the array.

`array.itemsize`

The length in bytes of one array item in the internal representation.

`array.append(x)`

Append a new item with value *x* to the end of the array.

`array.buffer_info()`

Return a tuple (*address*, *length*) giving the current memory address and the length in elements of the buffer used to hold array's contents. The size of the memory buffer in bytes can be computed as `array.buffer_info()[1] * array.itemsize`. This is occasionally useful when working with low-level (and inherently unsafe) I/O interfaces that require memory addresses, such as certain `ioctl()` operations. The returned numbers are valid as long as the array exists and no length-changing operations are applied to it.

---

**Note:** When using array objects from code written in C or C++ (the only way to effectively make use of this information), it makes more sense to use the buffer interface supported by array objects. This method is maintained for backward compatibility and should be avoided in new code. The buffer interface is documented in *bufferobjects*.

`array.byteswap()`

“Byteswap” all items of the array. This is only supported for values which are 1, 2, 4, or 8 bytes in size; for other types of values, `RuntimeError` is raised. It is useful when reading data from a file written on a machine with a different byte order.

`array.count(x)`

Return the number of occurrences of *x* in the array.

`array.extend(iterable)`

Append items from *iterable* to the end of the array. If *iterable* is another array, it must have *exactly* the same type code; if not, `TypeError` will be raised. If *iterable* is not an array, it must be iterable and its elements must be the right type to be appended to the array. Changed in version 2.4: Formerly, the argument could only be another array.

`array.fromfile(f, n)`

Read *n* items (as machine values) from the file object *f* and append them to the end of the array. If less than *n* items are available, `EOFError` is raised, but the items that were available are still inserted into the array. *f* must be a real built-in file object; something else with a `read()` method won’t do.

`array.fromlist(list)`

Append items from the list. This is equivalent to `for x in list: a.append(x)` except that if there is a type error, the array is unchanged.

`array.fromstring(s)`

Appends items from the string, interpreting the string as an array of machine values (as if it had been read from a file using the `fromfile()` method).

`array.fromunicode(s)`

Extends this array with data from the given unicode string. The array must be a type ‘u’ array; otherwise a `ValueError` is raised. Use `array.fromstring(unicodestring.encode(enc))` to append Unicode data to an array of some other type.

`array.index(x)`

Return the smallest *i* such that *i* is the index of the first occurrence of *x* in the array.

`array.insert(i, x)`

Insert a new item with value *x* in the array before position *i*. Negative values are treated as being relative to the end of the array.

`array.pop([i])`

Removes the item with the index *i* from the array and returns it. The optional argument defaults to `-1`, so that by default the last item is removed and returned.

`array.read(f, n)`

Deprecated since version 1.5.1: Use the `fromfile()` method. Read *n* items (as machine values) from the file object *f* and append them to the end of the array. If less than *n* items are available, `EOFError` is raised, but the items that were available are still inserted into the array. *f* must be a real built-in file object; something else with a `read()` method won’t do.

`array.remove(x)`

Remove the first occurrence of *x* from the array.

`array.reverse()`

Reverse the order of the items in the array.

`array.tofile(f)`

Write all items (as machine values) to the file object *f*.

`array.tolist()`

Convert the array to an ordinary list with the same items.

`array.tostring()`

Convert the array to an array of machine values and return the string representation (the same sequence of bytes that would be written to a file by the `tofile()` method.)

`array.tounicode()`

Convert the array to a unicode string. The array must be a type 'u' array; otherwise a `ValueError` is raised. Use `array.tostring().decode(enc)` to obtain a unicode string from an array of some other type.

`array.write(f)`

Deprecated since version 1.5.1: Use the `tofile()` method. Write all items (as machine values) to the file object *f*.

When an array object is printed or converted to a string, it is represented as `array(typecode, initializer)`. The *initializer* is omitted if the array is empty, otherwise it is a string if the *typecode* is 'c', otherwise it is a list of numbers. The string is guaranteed to be able to be converted back to an array with the same type and value using `eval()`, so long as the `array()` function has been imported using `from array import array`. Examples:

```
array('l')
array('c', 'hello world')
array('u', u'hello \u2641')
array('l', [1, 2, 3, 4, 5])
array('d', [1.0, 2.0, 3.14])
```

**See Also:**

**Module `struct`** Packing and unpacking of heterogeneous binary data.

**Module `xdrlib`** Packing and unpacking of External Data Representation (XDR) data as used in some remote procedure call systems.

**The Numerical Python Manual** The Numeric Python extension (NumPy) defines another array type; see <http://numpy.sourceforge.net/> for further information about Numerical Python. (A PDF version of the NumPy manual is available at <http://numpy.sourceforge.net/numdoc/numdoc.pdf>).

## 8.7 sets — Unordered collections of unique elements

New in version 2.3. Deprecated since version 2.6: The built-in `set/frozenset` types replace this module. The `sets` module provides classes for constructing and manipulating unordered collections of unique elements. Common uses include membership testing, removing duplicates from a sequence, and computing standard math operations on sets such as intersection, union, difference, and symmetric difference.

Like other collections, sets support `x in set`, `len(set)`, and `for x in set`. Being an unordered collection, sets do not record element position or order of insertion. Accordingly, sets do not support indexing, slicing, or other sequence-like behavior.

Most set applications use the `Set` class which provides every set method except for `__hash__()`. For advanced applications requiring a hash method, the `ImmutableSet` class adds a `__hash__()` method but omits methods which alter the contents of the set. Both `Set` and `ImmutableSet` derive from `BaseSet`, an abstract class useful for determining whether something is a set: `isinstance(obj, BaseSet)`.

The set classes are implemented using dictionaries. Accordingly, the requirements for set elements are the same as those for dictionary keys; namely, that the element defines both `__eq__()` and `__hash__()`. As a result, sets cannot contain mutable elements such as lists or dictionaries. However, they can contain immutable

collections such as tuples or instances of `ImmutableSet`. For convenience in implementing sets of sets, inner sets are automatically converted to immutable form, for example, `Set([Set(['dog'])])` is transformed to `Set([ImmutableSet(['dog'])])`.

**class** `sets.Set` (`[iterable]`)

Constructs a new empty `Set` object. If the optional `iterable` parameter is supplied, updates the set with elements obtained from iteration. All of the elements in `iterable` should be immutable or be transformable to an immutable using the protocol described in section *Protocol for automatic conversion to immutable*.

**class** `sets.ImmutableSet` (`[iterable]`)

Constructs a new empty `ImmutableSet` object. If the optional `iterable` parameter is supplied, updates the set with elements obtained from iteration. All of the elements in `iterable` should be immutable or be transformable to an immutable using the protocol described in section *Protocol for automatic conversion to immutable*.

Because `ImmutableSet` objects provide a `__hash__()` method, they can be used as set elements or as dictionary keys. `ImmutableSet` objects do not have methods for adding or removing elements, so all of the elements must be known when the constructor is called.

## 8.7.1 Set Objects

Instances of `Set` and `ImmutableSet` both provide the following operations:

Operation	Equivalent	Result
<code>len(s)</code>		cardinality of set <i>s</i>
<code>x in s</code>		test <i>x</i> for membership in <i>s</i>
<code>x not in s</code>		test <i>x</i> for non-membership in <i>s</i>
<code>s.issubset(t)</code>	<code>s &lt;= t</code>	test whether every element in <i>s</i> is in <i>t</i>
<code>s.issuperset(t)</code>	<code>s &gt;= t</code>	test whether every element in <i>t</i> is in <i>s</i>
<code>s.union(t)</code>	<code>s   t</code>	new set with elements from both <i>s</i> and <i>t</i>
<code>s.intersection(t)</code>	<code>s &amp; t</code>	new set with elements common to <i>s</i> and <i>t</i>
<code>s.difference(t)</code>	<code>s - t</code>	new set with elements in <i>s</i> but not in <i>t</i>
<code>s.symmetric_difference(t)</code>	<code>s ^ t</code>	new set with elements in either <i>s</i> or <i>t</i> but not both
<code>s.copy()</code>		new set with a shallow copy of <i>s</i>

Note, the non-operator versions of `union()`, `intersection()`, `difference()`, and `symmetric_difference()` will accept any iterable as an argument. In contrast, their operator based counterparts require their arguments to be sets. This precludes error-prone constructions like `Set('abc') & 'cbs'` in favor of the more readable `Set('abc').intersection('cbs')`. Changed in version 2.3.1: Formerly all arguments were required to be sets. In addition, both `Set` and `ImmutableSet` support set to set comparisons. Two sets are equal if and only if every element of each set is contained in the other (each is a subset of the other). A set is less than another set if and only if the first set is a proper subset of the second set (is a subset, but is not equal). A set is greater than another set if and only if the first set is a proper superset of the second set (is a superset, but is not equal).

The subset and equality comparisons do not generalize to a complete ordering function. For example, any two disjoint sets are not equal and are not subsets of each other, so *all* of the following return `False`: `a < b`, `a == b`, or `a > b`. Accordingly, sets do not implement the `__cmp__()` method.

Since sets only define partial ordering (subset relationships), the output of the `list.sort()` method is undefined for lists of sets.

The following table lists operations available in `ImmutableSet` but not found in `Set`:

Operation	Result
<code>hash(s)</code>	returns a hash value for <i>s</i>

The following table lists operations available in `Set` but not found in `ImmutableSet`:

Operation	Equivalent	Result
<code>s.update(t)</code>	$s \mid= t$	return set <i>s</i> with elements added from <i>t</i>
<code>s.intersection_update(t)</code>	$s \&= t$	return set <i>s</i> keeping only elements also found in <i>t</i>
<code>s.difference_update(t)</code>	$s -= t$	return set <i>s</i> after removing elements found in <i>t</i>
<code>s.symmetric_difference_update(t)</code>	$s \wedge t$	return set <i>s</i> with elements from <i>s</i> or <i>t</i> but not both
<code>s.add(x)</code>		add element <i>x</i> to set <i>s</i>
<code>s.remove(x)</code>		remove <i>x</i> from set <i>s</i> ; raises <code>KeyError</code> if not present
<code>s.discard(x)</code>		removes <i>x</i> from set <i>s</i> if present
<code>s.pop()</code>		remove and return an arbitrary element from <i>s</i> ; raises <code>KeyError</code> if empty
<code>s.clear()</code>		remove all elements from set <i>s</i>

Note, the non-operator versions of `update()`, `intersection_update()`, `difference_update()`, and `symmetric_difference_update()` will accept any iterable as an argument. Changed in version 2.3.1: Formerly all arguments were required to be sets. Also note, the module also includes a `union_update()` method which is an alias for `update()`. The method is included for backwards compatibility. Programmers should prefer the `update()` method because it is supported by the built-in `set()` and `frozenset()` types.

## 8.7.2 Example

```
>>> from sets import Set
>>> engineers = Set(['John', 'Jane', 'Jack', 'Janice'])
>>> programmers = Set(['Jack', 'Sam', 'Susan', 'Janice'])
>>> managers = Set(['Jane', 'Jack', 'Susan', 'Zack'])
>>> employees = engineers | programmers | managers           # union
>>> engineering_management = engineers & managers           # intersection
>>> fulltime_management = managers - engineers - programmers # difference
>>> engineers.add('Marvin')                                  # add element
>>> print engineers
Set(['Jane', 'Marvin', 'Janice', 'John', 'Jack'])
>>> employees.issuperset(engineers)                         # superset test
False
>>> employees.update(engineers)                             # update from another set
>>> employees.issuperset(engineers)
True
>>> for group in [engineers, programmers, managers, employees]:
...     group.discard('Susan')                             # unconditionally remove element
...     print group
...
Set(['Jane', 'Marvin', 'Janice', 'John', 'Jack'])
Set(['Janice', 'Jack', 'Sam'])
Set(['Jane', 'Zack', 'Jack'])
Set(['Jack', 'Sam', 'Jane', 'Marvin', 'Janice', 'John', 'Zack'])
```

## 8.7.3 Protocol for automatic conversion to immutable

Sets can only contain immutable elements. For convenience, mutable `Set` objects are automatically copied to an `ImmutableSet` before being added as a set element.

The mechanism is to always add a *hashable* element, or if it is not hashable, the element is checked to see if it has an `__as_immutable__()` method which returns an immutable equivalent.

Since `Set` objects have a `__as_immutable__()` method returning an instance of `ImmutableSet`, it is possible to construct sets of sets.

A similar mechanism is needed by the `__contains__()` and `remove()` methods which need to hash an element to check for membership in a set. Those methods check an element for hashability and, if not, check for a `__as_temporarily_immutable__()` method which returns the element wrapped by a class that provides temporary methods for `__hash__()`, `__eq__()`, and `__ne__()`.

The alternate mechanism spares the need to build a separate copy of the original mutable object.

`Set` objects implement the `__as_temporarily_immutable__()` method which returns the `Set` object wrapped by a new class `_TemporarilyImmutableSet`.

The two mechanisms for adding hashability are normally invisible to the user; however, a conflict can arise in a multi-threaded environment where one thread is updating a set while another has temporarily wrapped it in `_TemporarilyImmutableSet`. In other words, sets of mutable sets are not thread-safe.

## 8.7.4 Comparison to the built-in set types

The built-in `set` and `frozenset` types were designed based on lessons learned from the `sets` module. The key differences are:

- `Set` and `ImmutableSet` were renamed to `set` and `frozenset`.
- There is no equivalent to `BaseSet`. Instead, use `isinstance(x, (set, frozenset))`.
- The hash algorithm for the built-ins performs significantly better (fewer collisions) for most datasets.
- The built-in versions have more space efficient pickles.
- The built-in versions do not have a `union_update()` method. Instead, use the `update()` method which is equivalent.
- The built-in versions do not have a `__repr(sorted=True)` method. Instead, use the built-in `repr()` and `sorted()` functions: `repr(sorted(s))`.
- The built-in version does not have a protocol for automatic conversion to immutable. Many found this feature to be confusing and no one in the community reported having found real uses for it.

## 8.8 sched — Event scheduler

Source code: [Lib/sched.py](#)

The `sched` module defines a class which implements a general purpose event scheduler:

```
class sched.scheduler(timefunc, delayfunc)
```

The `scheduler` class defines a generic interface to scheduling events. It needs two functions to actually deal with the “outside world” — `timefunc` should be callable without arguments, and return a number (the “time”, in any units whatsoever). The `delayfunc` function should be callable with one argument, compatible with the output of `timefunc`, and should delay that many time units. `delayfunc` will also be called with the argument 0 after each event is run to allow other threads an opportunity to run in multi-threaded applications.

Example:

```
>>> import sched, time
>>> s = sched.scheduler(time.time, time.sleep)
>>> def print_time(): print "From print_time", time.time()
```

```
...
>>> def print_some_times():
...     print time.time()
...     s.enter(5, 1, print_time, ())
...     s.enter(10, 1, print_time, ())
...     s.run()
...     print time.time()
...
>>> print_some_times()
930343690.257
From print_time 930343695.274
From print_time 930343700.273
930343700.276
```

In multi-threaded environments, the `scheduler` class has limitations with respect to thread-safety, inability to insert a new task before the one currently pending in a running scheduler, and holding up the main thread until the event queue is empty. Instead, the preferred approach is to use the `threading.Timer` class instead.

Example:

```
>>> import time
>>> from threading import Timer
>>> def print_time():
...     print "From print_time", time.time()
...
>>> def print_some_times():
...     print time.time()
...     Timer(5, print_time, ()).start()
...     Timer(10, print_time, ()).start()
...     time.sleep(11) # sleep while time-delay events execute
...     print time.time()
...
>>> print_some_times()
930343690.257
From print_time 930343695.274
From print_time 930343700.273
930343701.301
```

## 8.8.1 Scheduler Objects

`scheduler` instances have the following methods and attributes:

`scheduler.enterabs` (*time, priority, action, argument*)

Schedule a new event. The *time* argument should be a numeric type compatible with the return value of the *timefunc* function passed to the constructor. Events scheduled for the same *time* will be executed in the order of their *priority*.

Executing the event means executing `action(*argument)`. *argument* must be a sequence holding the parameters for *action*.

Return value is an event which may be used for later cancellation of the event (see `cancel()`).

`scheduler.enter` (*delay, priority, action, argument*)

Schedule an event for *delay* more time units. Other than the relative time, the other arguments, the effect and the return value are the same as those for `enterabs()`.

`scheduler.cancel(event)`

Remove the event from the queue. If *event* is not an event currently in the queue, this method will raise a `ValueError`.

`scheduler.empty()`

Return true if the event queue is empty.

`scheduler.run()`

Run all scheduled events. This function will wait (using the `delayfunc()` function passed to the constructor) for the next event, then execute it and so on until there are no more scheduled events.

Either *action* or *delayfunc* can raise an exception. In either case, the scheduler will maintain a consistent state and propagate the exception. If an exception is raised by *action*, the event will not be attempted in future calls to `run()`.

If a sequence of events takes longer to run than the time available before the next event, the scheduler will simply fall behind. No events will be dropped; the calling code is responsible for canceling events which are no longer pertinent.

`scheduler.queue`

Read-only attribute returning a list of upcoming events in the order they will be run. Each event is shown as a *named tuple* with the following fields: time, priority, action, argument. New in version 2.6.

## 8.9 mutex — Mutual exclusion support

Deprecated since version 2.6: The `mutex` module has been removed in Python 3. The `mutex` module defines a class that allows mutual-exclusion via acquiring and releasing locks. It does not require (or imply) `threading` or multi-tasking, though it could be useful for those purposes.

The `mutex` module defines the following class:

**class** `mutex.mutex`

Create a new (unlocked) mutex.

A mutex has two pieces of state — a “locked” bit and a queue. When the mutex is not locked, the queue is empty. Otherwise, the queue contains zero or more (`function, argument`) pairs representing functions (or methods) waiting to acquire the lock. When the mutex is unlocked while the queue is not empty, the first queue entry is removed and its `function(argument)` pair called, implying it now has the lock.

Of course, no multi-threading is implied – hence the funny interface for `lock()`, where a function is called once the lock is acquired.

### 8.9.1 Mutex Objects

`mutex` objects have following methods:

`mutex.test()`

Check whether the mutex is locked.

`mutex.testandset()`

“Atomic” test-and-set, grab the lock if it is not set, and return `True`, otherwise, return `False`.

`mutex.lock(function, argument)`

Execute `function(argument)`, unless the mutex is locked. In the case it is locked, place the function and argument on the queue. See `unlock()` for explanation of when `function(argument)` is executed in that case.

`mutex.unlock()`

Unlock the mutex if queue is empty, otherwise execute the first element in the queue.

## 8.10 Queue — A synchronized queue class

---

**Note:** The `Queue` module has been renamed to `queue` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

**Source code:** [Lib/Queue.py](#)

---

The `Queue` module implements multi-producer, multi-consumer queues. It is especially useful in threaded programming when information must be exchanged safely between multiple threads. The `Queue` class in this module implements all the required locking semantics. It depends on the availability of thread support in Python; see the `threading` module.

The module implements three types of queue, which differ only in the order in which the entries are retrieved. In a FIFO queue, the first tasks added are the first retrieved. In a LIFO queue, the most recently added entry is the first retrieved (operating like a stack). With a priority queue, the entries are kept sorted (using the `heapq` module) and the lowest valued entry is retrieved first.

The `Queue` module defines the following classes and exceptions:

**class** `Queue.Queue` (*maxsize=0*)

Constructor for a FIFO queue. *maxsize* is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite.

**class** `Queue.LifoQueue` (*maxsize=0*)

Constructor for a LIFO queue. *maxsize* is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite. New in version 2.6.

**class** `Queue.PriorityQueue` (*maxsize=0*)

Constructor for a priority queue. *maxsize* is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite.

The lowest valued entries are retrieved first (the lowest valued entry is the one returned by `sorted(list(entries))[0]`). A typical pattern for entries is a tuple in the form: `(priority_number, data)`. New in version 2.6.

**exception** `Queue.Empty`

Exception raised when non-blocking `get()` (or `get_nowait()`) is called on a `Queue` object which is empty.

**exception** `Queue.Full`

Exception raised when non-blocking `put()` (or `put_nowait()`) is called on a `Queue` object which is full.

**See Also:**

`collections.deque` is an alternative implementation of unbounded queues with fast atomic `append()` and `popleft()` operations that do not require locking.

## 8.10.1 Queue Objects

Queue objects (`Queue`, `LifoQueue`, or `PriorityQueue`) provide the public methods described below.

`Queue.qsize()`

Return the approximate size of the queue. Note, `qsize() > 0` doesn't guarantee that a subsequent `get()` will not block, nor will `qsize() < maxsize` guarantee that `put()` will not block.

`Queue.empty()`

Return `True` if the queue is empty, `False` otherwise. If `empty()` returns `True` it doesn't guarantee that a subsequent call to `put()` will not block. Similarly, if `empty()` returns `False` it doesn't guarantee that a subsequent call to `get()` will not block.

`Queue.full()`

Return `True` if the queue is full, `False` otherwise. If `full()` returns `True` it doesn't guarantee that a subsequent call to `get()` will not block. Similarly, if `full()` returns `False` it doesn't guarantee that a subsequent call to `put()` will not block.

`Queue.put(item[, block[, timeout]])`

Put `item` into the queue. If optional args `block` is true and `timeout` is `None` (the default), block if necessary until a free slot is available. If `timeout` is a positive number, it blocks at most `timeout` seconds and raises the `Full` exception if no free slot was available within that time. Otherwise (`block` is false), put an item on the queue if a free slot is immediately available, else raise the `Full` exception (`timeout` is ignored in that case). New in version 2.3: The `timeout` parameter.

`Queue.put_nowait(item)`

Equivalent to `put(item, False)`.

`Queue.get([block[, timeout]])`

Remove and return an item from the queue. If optional args `block` is true and `timeout` is `None` (the default), block if necessary until an item is available. If `timeout` is a positive number, it blocks at most `timeout` seconds and raises the `Empty` exception if no item was available within that time. Otherwise (`block` is false), return an item if one is immediately available, else raise the `Empty` exception (`timeout` is ignored in that case). New in version 2.3: The `timeout` parameter.

`Queue.get_nowait()`

Equivalent to `get(False)`.

Two methods are offered to support tracking whether enqueued tasks have been fully processed by daemon consumer threads.

`Queue.task_done()`

Indicate that a formerly enqueued task is complete. Used by queue consumer threads. For each `get()` used to fetch a task, a subsequent call to `task_done()` tells the queue that the processing on the task is complete.

If a `join()` is currently blocking, it will resume when all items have been processed (meaning that a `task_done()` call was received for every item that had been `put()` into the queue).

Raises a `ValueError` if called more times than there were items placed in the queue. New in version 2.5.

`Queue.join()`

Blocks until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls `task_done()` to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, `join()` unblocks. New in version 2.5.

Example of how to wait for enqueued tasks to be completed:

```
def worker():
    while True:
```

```
        item = q.get()
        do_work(item)
        q.task_done()

q = Queue()
for i in range(num_worker_threads):
    t = Thread(target=worker)
    t.daemon = True
    t.start()

for item in source():
    q.put(item)

q.join()          # block until all tasks are done
```

## 8.11 weakref — Weak references

New in version 2.1. **Source code:** [Lib/weakref.py](#)

---

The `weakref` module allows the Python programmer to create *weak references* to objects.

In the following, the term *referent* means the object which is referred to by a weak reference.

A weak reference to an object is not enough to keep the object alive: when the only remaining references to a referent are weak references, *garbage collection* is free to destroy the referent and reuse its memory for something else. A primary use for weak references is to implement caches or mappings holding large objects, where it's desired that a large object not be kept alive solely because it appears in a cache or mapping.

For example, if you have a number of large binary image objects, you may wish to associate a name with each. If you used a Python dictionary to map names to images, or images to names, the image objects would remain alive just because they appeared as values or keys in the dictionaries. The `WeakKeyDictionary` and `WeakValueDictionary` classes supplied by the `weakref` module are an alternative, using weak references to construct mappings that don't keep objects alive solely because they appear in the mapping objects. If, for example, an image object is a value in a `WeakValueDictionary`, then when the last remaining references to that image object are the weak references held by weak mappings, garbage collection can reclaim the object, and its corresponding entries in weak mappings are simply deleted.

`WeakKeyDictionary` and `WeakValueDictionary` use weak references in their implementation, setting up callback functions on the weak references that notify the weak dictionaries when a key or value has been reclaimed by garbage collection. Most programs should find that using one of these weak dictionary types is all they need – it's not usually necessary to create your own weak references directly. The low-level machinery used by the weak dictionary implementations is exposed by the `weakref` module for the benefit of advanced uses.

Not all objects can be weakly referenced; those objects which can include class instances, functions written in Python (but not in C), methods (both bound and unbound), sets, frozensets, file objects, *generators*, type objects, `DBcursor` objects from the `bsddb` module, sockets, arrays, dequeues, regular expression pattern objects, and code objects. Changed in version 2.4: Added support for files, sockets, arrays, and patterns. Changed in version 2.7: Added support for `thread.lock`, `threading.Lock`, and code objects. Several built-in types such as `list` and `dict` do not directly support weak references but can add support through subclassing:

```
class Dict(dict):
    pass

obj = Dict(red=1, green=2, blue=3)  # this object is weak referenceable
```

**CPython implementation detail:** Other built-in types such as `tuple` and `long` do not support weak references even when subclassed.

Extension types can easily be made to support weak references; see *weakref-support*.

**class** `weakref.ref` (*object* [, *callback* ])

Return a weak reference to *object*. The original object can be retrieved by calling the reference object if the referent is still alive; if the referent is no longer alive, calling the reference object will cause `None` to be returned. If *callback* is provided and not `None`, and the returned weakref object is still alive, the callback will be called when the object is about to be finalized; the weak reference object will be passed as the only parameter to the callback; the referent will no longer be available.

It is allowable for many weak references to be constructed for the same object. Callbacks registered for each weak reference will be called from the most recently registered callback to the oldest registered callback.

Exceptions raised by the callback will be noted on the standard error output, but cannot be propagated; they are handled in exactly the same way as exceptions raised from an object's `__del__()` method.

Weak references are *hashable* if the *object* is hashable. They will maintain their hash value even after the *object* was deleted. If `hash()` is called the first time only after the *object* was deleted, the call will raise `TypeError`.

Weak references support tests for equality, but not ordering. If the referents are still alive, two references have the same equality relationship as their referents (regardless of the *callback*). If either referent has been deleted, the references are equal only if the reference objects are the same object. Changed in version 2.4: This is now a subclassable type rather than a factory function; it derives from `object`.

`weakref.proxy` (*object* [, *callback* ])

Return a proxy to *object* which uses a weak reference. This supports use of the proxy in most contexts instead of requiring the explicit dereferencing used with weak reference objects. The returned object will have a type of either `ProxyType` or `CallableProxyType`, depending on whether *object* is callable. Proxy objects are not *hashable* regardless of the referent; this avoids a number of problems related to their fundamentally mutable nature, and prevent their use as dictionary keys. *callback* is the same as the parameter of the same name to the `ref()` function.

`weakref.getweakrefcount` (*object*)

Return the number of weak references and proxies which refer to *object*.

`weakref.getweakrefs` (*object*)

Return a list of all weak reference and proxy objects which refer to *object*.

**class** `weakref.WeakKeyDictionary` ([*dict* ])

Mapping class that references keys weakly. Entries in the dictionary will be discarded when there is no longer a strong reference to the key. This can be used to associate additional data with an object owned by other parts of an application without adding attributes to those objects. This can be especially useful with objects that override attribute accesses.

---

**Note:** Caution: Because a `WeakKeyDictionary` is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a `WeakKeyDictionary` because actions performed by the program during iteration may cause items in the dictionary to vanish “by magic” (as a side effect of garbage collection).

---

`WeakKeyDictionary` objects have the following additional methods. These expose the internal references directly. The references are not guaranteed to be “live” at the time they are used, so the result of calling the references needs to be checked before being used. This can be used to avoid creating references that will cause the garbage collector to keep the keys around longer than needed.

`WeakKeyDictionary.iterkeyrefs` ()

Return an *iterator* that yields the weak references to the keys. New in version 2.5.

`WeakKeyDictionary.keyrefs()`

Return a list of weak references to the keys. New in version 2.5.

**class** `weakref.WeakValueDictionary` (`[dict]`)

Mapping class that references values weakly. Entries in the dictionary will be discarded when no strong reference to the value exists any more.

---

**Note:** Caution: Because a `WeakValueDictionary` is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a `WeakValueDictionary` because actions performed by the program during iteration may cause items in the dictionary to vanish “by magic” (as a side effect of garbage collection).

---

`WeakValueDictionary` objects have the following additional methods. These methods have the same issues as the `iterkeyrefs()` and `keyrefs()` methods of `WeakKeyDictionary` objects.

`WeakValueDictionary.itervaluerefs()`

Return an *iterator* that yields the weak references to the values. New in version 2.5.

`WeakValueDictionary.valuerefs()`

Return a list of weak references to the values. New in version 2.5.

**class** `weakref.WeakSet` (`[elements]`)

Set class that keeps weak references to its elements. An element will be discarded when no strong reference to it exists any more. New in version 2.7.

`weakref.ReferenceType`

The type object for weak references objects.

`weakref.ProxyType`

The type object for proxies of objects which are not callable.

`weakref.CallableProxyType`

The type object for proxies of callable objects.

`weakref.ProxyTypes`

Sequence containing all the type objects for proxies. This can make it simpler to test if an object is a proxy without being dependent on naming both proxy types.

**exception** `weakref.ReferenceError`

Exception raised when a proxy object is used but the underlying object has been collected. This is the same as the standard `ReferenceError` exception.

**See Also:**

**PEP 0205 - Weak References** The proposal and rationale for this feature, including links to earlier implementations and information about similar features in other languages.

### 8.11.1 Weak Reference Objects

Weak reference objects have no attributes or methods, but do allow the referent to be obtained, if it still exists, by calling it:

```
>>> import weakref
>>> class Object:
...     pass
...
>>> o = Object()
>>> r = weakref.ref(o)
```

```
>>> o2 = r()
>>> o is o2
True
```

If the referent no longer exists, calling the reference object returns `None`:

```
>>> del o, o2
>>> print r()
None
```

Testing that a weak reference object is still live should be done using the expression `ref() is not None`. Normally, application code that needs to use a reference object should follow this pattern:

```
# r is a weak reference object
o = r()
if o is None:
    # referent has been garbage collected
    print "Object has been deallocated; can't frobnicate."
else:
    print "Object is still live!"
    o.do_something_useful()
```

Using a separate test for “liveness” creates race conditions in threaded applications; another thread can cause a weak reference to become invalidated before the weak reference is called; the idiom shown above is safe in threaded applications as well as single-threaded applications.

Specialized versions of `ref` objects can be created through subclassing. This is used in the implementation of the `WeakValueDictionary` to reduce the memory overhead for each entry in the mapping. This may be most useful to associate additional information with a reference, but could also be used to insert additional processing on calls to retrieve the referent.

This example shows how a subclass of `ref` can be used to store additional information about an object and affect the value that’s returned when the referent is accessed:

```
import weakref
```

```
class ExtendedRef(weakref.ref):
    def __init__(self, ob, callback=None, **annotations):
        super(ExtendedRef, self).__init__(ob, callback)
        self.__counter = 0
        for k, v in annotations.iteritems():
            setattr(self, k, v)

    def __call__(self):
        """Return a pair containing the referent and the number of
        times the reference has been called.
        """
        ob = super(ExtendedRef, self).__call__()
        if ob is not None:
            self.__counter += 1
            ob = (ob, self.__counter)
        return ob
```

### 8.11.2 Example

This simple example shows how an application can use objects IDs to retrieve objects that it has seen before. The IDs of the objects can then be used in other data structures without forcing the objects to remain alive, but the objects can

still be retrieved by ID if they do.

```
import weakref

_id2obj_dict = weakref.WeakValueDictionary()

def remember(obj):
    oid = id(obj)
    _id2obj_dict[oid] = obj
    return oid

def id2obj(oid):
    return _id2obj_dict[oid]
```

## 8.12 UserDict — Class wrapper for dictionary objects

Source code: [Lib/UserDict.py](#)

---

The module defines a mixin, `DictMixin`, defining all dictionary methods for classes that already have a minimum mapping interface. This greatly simplifies writing classes that need to be substitutable for dictionaries (such as the `shelve` module).

This module also defines a class, `UserDict`, that acts as a wrapper around dictionary objects. The need for this class has been largely supplanted by the ability to subclass directly from `dict` (a feature that became available starting with Python version 2.2). Prior to the introduction of `dict`, the `UserDict` class was used to create dictionary-like sub-classes that obtained new behaviors by overriding existing methods or adding new ones.

The `UserDict` module defines the `UserDict` class and `DictMixin`:

```
class UserDict.UserDict ([initialdata])
    Class that simulates a dictionary. The instance's contents are kept in a regular dictionary, which is accessible via the data attribute of UserDict instances. If initialdata is provided, data is initialized with its contents; note that a reference to initialdata will not be kept, allowing it be used for other purposes.
```

---

**Note:** For backward compatibility, instances of `UserDict` are not iterable.

---

```
class UserDict.IterableUserDict ([initialdata])
    Subclass of UserDict that supports direct iteration (e.g. for key in myDict).
```

In addition to supporting the methods and operations of mappings (see section *Mapping Types — dict*), `UserDict` and `IterableUserDict` instances provide the following attribute:

```
IterableUserDict.data
    A real dictionary used to store the contents of the UserDict class.
```

```
class UserDict.DictMixin
    Mixin defining all dictionary methods for classes that already have a minimum dictionary interface including __getitem__(), __setitem__(), __delitem__(), and keys().
```

This mixin should be used as a superclass. Adding each of the above methods adds progressively more functionality. For instance, defining all but `__delitem__()` will preclude only `pop()` and `popitem()` from the full interface.

In addition to the four base methods, progressively more efficiency comes with defining `__contains__()`, `__iter__()`, and `iteritems()`.

Since the mixin has no knowledge of the subclass constructor, it does not define `__init__()` or `copy()`.

Starting with Python version 2.6, it is recommended to use `collections.MutableMapping` instead of `DictMixin`.

## 8.13 `UserList` — Class wrapper for list objects

**Note:** When Python 2.2 was released, many of the use cases for this class were subsumed by the ability to subclass `list` directly. However, a handful of use cases remain.

This module provides a list-interface around an underlying data store. By default, that data store is a `list`; however, it can be used to wrap a list-like interface around other objects (such as persistent storage).

In addition, this class can be mixed-in with built-in classes using multiple inheritance. This can sometimes be useful. For example, you can inherit from `UserList` and `str` at the same time. That would not be possible with both a real `list` and a real `str`.

This module defines a class that acts as a wrapper around list objects. It is a useful base class for your own list-like classes, which can inherit from them and override existing methods or add new ones. In this way one can add new behaviors to lists.

The `UserList` module defines the `UserList` class:

```
class UserList.UserList ([list])
```

Class that simulates a list. The instance's contents are kept in a regular list, which is accessible via the `data` attribute of `UserList` instances. The instance's contents are initially set to a copy of `list`, defaulting to the empty list `[]`. `list` can be any iterable, e.g. a real Python list or a `UserList` object.

**Note:** The `UserList` class has been moved to the `collections` module in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

In addition to supporting the methods and operations of mutable sequences (see section *Sequence Types — str, unicode, list, tuple, bytearray, buffer, xrange*), `UserList` instances provide the following attribute:

`UserList.data`

A real Python list object used to store the contents of the `UserList` class.

**Subclassing requirements:** Subclasses of `UserList` are expected to offer a constructor which can be called with either no arguments or one argument. List operations which return a new sequence attempt to create an instance of the actual implementation class. To do so, it assumes that the constructor can be called with a single parameter, which is a sequence object used as a data source.

If a derived class does not wish to comply with this requirement, all of the special methods supported by this class will need to be overridden; please consult the sources for information about the methods which need to be provided in that case. Changed in version 2.0: Python versions 1.5.2 and 1.6 also required that the constructor be callable with no parameters, and offer a mutable `data` attribute. Earlier versions of Python did not attempt to create instances of the derived class.

## 8.14 `UserString` — Class wrapper for string objects

**Note:** This `UserString` class from this module is available for backward compatibility only. If you are writing code that does not need to work with versions of Python earlier than Python 2.2, please consider subclassing directly from the built-in `str` type instead of using `UserString` (there is no built-in equivalent to `MutableString`).

---

This module defines a class that acts as a wrapper around string objects. It is a useful base class for your own string-like classes, which can inherit from them and override existing methods or add new ones. In this way one can add new behaviors to strings.

It should be noted that these classes are highly inefficient compared to real string or Unicode objects; this is especially the case for `MutableString`.

The `UserString` module defines the following classes:

**class** `UserString.UserString` (`[sequence]`)

Class that simulates a string or a Unicode string object. The instance's content is kept in a regular string or Unicode string object, which is accessible via the `data` attribute of `UserString` instances. The instance's contents are initially set to a copy of `sequence`. `sequence` can be either a regular Python string or Unicode string, an instance of `UserString` (or a subclass) or an arbitrary sequence which can be converted into a string using the built-in `str()` function.

---

**Note:** The `UserString` class has been moved to the `collections` module in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

**class** `UserString.MutableString` (`[sequence]`)

This class is derived from the `UserString` above and redefines strings to be *mutable*. Mutable strings can't be used as dictionary keys, because dictionaries require *immutable* objects as keys. The main intention of this class is to serve as an educational example for inheritance and necessity to remove (override) the `__hash__()` method in order to trap attempts to use a mutable object as dictionary key, which would be otherwise very error prone and hard to track down. Deprecated since version 2.6: The `MutableString` class has been removed in Python 3.

In addition to supporting the methods and operations of string and Unicode objects (see section [String Methods](#)), `UserString` instances provide the following attribute:

`MutableString.data`

A real Python string or Unicode object used to store the content of the `UserString` class.

## 8.15 types — Names for built-in types

Source code: [Lib/types.py](#)

---

This module defines names for some object types that are used by the standard Python interpreter, but not for the types defined by various extension modules. Also, it does not include some of the types that arise during processing such as the `listiterator` type. It is safe to use `from types import *` — the module does not export any names besides the ones listed here. New names exported by future versions of this module will all end in `Type`.

Typical use is for functions that do different things depending on their argument types, like the following:

```
from types import *
def delete(mylist, item):
    if type(item) is IntType:
        del mylist[item]
    else:
        mylist.remove(item)
```

Starting in Python 2.2, built-in factory functions such as `int()` and `str()` are also names for the corresponding types. This is now the preferred way to access the type instead of using the `types` module. Accordingly, the example above should be written as follows:

```
def delete(mylist, item):
    if isinstance(item, int):
        del mylist[item]
    else:
        mylist.remove(item)
```

The module defines the following names:

`types.NoneType`

The type of `None`.

`types.TypeType`

The type of type objects (such as returned by `type()`); alias of the built-in `type`.

`types.BooleanType`

The type of the `bool` values `True` and `False`; alias of the built-in `bool`. New in version 2.3.

`types.IntType`

The type of integers (e.g. `1`); alias of the built-in `int`.

`types.LongType`

The type of long integers (e.g. `1L`); alias of the built-in `long`.

`types.FloatType`

The type of floating point numbers (e.g. `1.0`); alias of the built-in `float`.

`types.ComplexType`

The type of complex numbers (e.g. `1.0j`). This is not defined if Python was built without complex number support.

`types.StringType`

The type of character strings (e.g. `'Spam'`); alias of the built-in `str`.

`types.UnicodeType`

The type of Unicode character strings (e.g. `u'Spam'`). This is not defined if Python was built without Unicode support. It's an alias of the built-in `unicode`.

`types.TupleType`

The type of tuples (e.g. `(1, 2, 3, 'Spam')`); alias of the built-in `tuple`.

`types.ListType`

The type of lists (e.g. `[0, 1, 2, 3]`); alias of the built-in `list`.

`types.DictType`

The type of dictionaries (e.g. `{'Bacon': 1, 'Ham': 0}`); alias of the built-in `dict`.

`types.DictionaryType`

An alternate name for `DictType`.

`types.FunctionType`

`types.LambdaType`

The type of user-defined functions and functions created by `lambda` expressions.

`types.GeneratorType`

The type of *generator*-iterator objects, produced by calling a generator function. New in version 2.2.

`types.CodeType`

The type for code objects such as returned by `compile()`.

### `types.ClassType`

The type of user-defined old-style classes.

### `types.InstanceType`

The type of instances of user-defined classes.

### `types.MethodType`

The type of methods of user-defined class instances.

### `types.UnboundMethodType`

An alternate name for `MethodType`.

### `types.BuiltinFunctionType`

### `types.BuiltinMethodType`

The type of built-in functions like `len()` or `sys.exit()`, and methods of built-in classes. (Here, the term “built-in” means “written in C”.)

### `types.ModuleType`

The type of modules.

### `types.FileType`

The type of open file objects such as `sys.stdout`; alias of the built-in `file`.

### `types.XRangeType`

The type of range objects returned by `xrange()`; alias of the built-in `xrange`.

### `types.SliceType`

The type of objects returned by `slice()`; alias of the built-in `slice`.

### `types.EllipsisType`

The type of `Ellipsis`.

### `types.TracebackType`

The type of traceback objects such as found in `sys.exc_traceback`.

### `types.FrameType`

The type of frame objects such as found in `tb.tb_frame` if `tb` is a traceback object.

### `types.BufferType`

The type of buffer objects created by the `buffer()` function.

### `types.DictProxyType`

The type of dict proxies, such as `TypeType.__dict__`.

### `types.NotImplementedType`

The type of `NotImplemented`

### `types.GetSetDescriptorType`

The type of objects defined in extension modules with `PyGetSetDef`, such as `FrameType.f_locals` or `array.array.typecode`. This type is used as descriptor for object attributes; it has the same purpose as the `property` type, but for classes defined in extension modules. New in version 2.5.

### `types.MemberDescriptorType`

The type of objects defined in extension modules with `PyMemberDef`, such as `datetime.timedelta.days`. This type is used as descriptor for simple C data members which use standard conversion functions; it has the same purpose as the `property` type, but for classes defined in extension modules.

**CPython implementation detail:** In other implementations of Python, this type may be identical to `GetSetDescriptorType`. New in version 2.5.

**types.StringTypes**

A sequence containing `StringType` and `UnicodeType` used to facilitate easier checking for any string object. Using this is more portable than using a sequence of the two string types constructed elsewhere since it only contains `UnicodeType` if it has been built in the running version of Python. For example: `isinstance(s, types.StringTypes)`. New in version 2.2.

## 8.16 new — Creation of runtime internal objects

Deprecated since version 2.6: The `new` module has been removed in Python 3. Use the `types` module's classes instead. The `new` module allows an interface to the interpreter object creation functions. This is for use primarily in marshal-type functions, when a new object needs to be created “magically” and not by using the regular creation functions. This module provides a low-level interface to the interpreter, so care must be exercised when using this module. It is possible to supply non-sensical arguments which crash the interpreter when the object is used.

The `new` module defines the following functions:

`new.instance` (*class* [, *dict* ])

This function creates an instance of *class* with dictionary *dict* without calling the `__init__()` constructor. If *dict* is omitted or `None`, a new, empty dictionary is created for the new instance. Note that there are no guarantees that the object will be in a consistent state.

`newinstancemethod` (*function*, *instance*, *class*)

This function will return a method object, bound to *instance*, or unbound if *instance* is `None`. *function* must be callable.

`new.function` (*code*, *globals* [, *name* [, *argdefs* [, *closure* ]]]])

Returns a (Python) function with the given code and globals. If *name* is given, it must be a string or `None`. If it is a string, the function will have the given name, otherwise the function name will be taken from `code.co_name`. If *argdefs* is given, it must be a tuple and will be used to determine the default values of parameters. If *closure* is given, it must be `None` or a tuple of cell objects containing objects to bind to the names in `code.co_freevars`.

`new.code` (*argcount*, *nlocals*, *stacksize*, *flags*, *codestring*, *constants*, *names*, *varnames*, *filename*, *name*, *firstlineno*, *lnotab*)

This function is an interface to the `PyCode_New()` C function.

`new.module` (*name* [, *doc* ])

This function returns a new module object with name *name*. *name* must be a string. The optional *doc* argument can have any type.

`new.classobj` (*name*, *baseclasses*, *dict*)

This function returns a new class object, with name *name*, derived from *baseclasses* (which should be a tuple of classes) and with namespace *dict*.

## 8.17 copy — Shallow and deep copy operations

Assignment statements in Python do not copy objects, they create bindings between a target and an object. For collections that are mutable or contain mutable items, a copy is sometimes needed so one can change one copy without changing the other. This module provides generic shallow and deep copy operations (explained below).

Interface summary:

`copy.copy` (*x*)

Return a shallow copy of *x*.

`copy.deepcopy(x)`  
Return a deep copy of *x*.

**exception** `copy.error`  
Raised for module specific errors.

The difference between shallow and deep copying is only relevant for compound objects (objects that contain other objects, like lists or class instances):

- A *shallow copy* constructs a new compound object and then (to the extent possible) inserts *references* into it to the objects found in the original.
- A *deep copy* constructs a new compound object and then, recursively, inserts *copies* into it of the objects found in the original.

Two problems often exist with deep copy operations that don't exist with shallow copy operations:

- Recursive objects (compound objects that, directly or indirectly, contain a reference to themselves) may cause a recursive loop.
- Because deep copy copies *everything* it may copy too much, e.g., administrative data structures that should be shared even between copies.

The `deepcopy()` function avoids these problems by:

- keeping a “memo” dictionary of objects already copied during the current copying pass; and
- letting user-defined classes override the copying operation or the set of components copied.

This module does not copy types like module, method, stack trace, stack frame, file, socket, window, array, or any similar types. It does “copy” functions and classes (shallow and deeply), by returning the original object unchanged; this is compatible with the way these are treated by the `pickle` module.

Shallow copies of dictionaries can be made using `dict.copy()`, and of lists by assigning a slice of the entire list, for example, `copied_list = original_list[:]`. Changed in version 2.5: Added copying functions. Classes can use the same interfaces to control copying that they use to control pickling. See the description of module `pickle` for information on these methods. The `copy` module does not use the `copy_reg` registration module.

In order for a class to define its own copy implementation, it can define special methods `__copy__()` and `__deepcopy__()`. The former is called to implement the shallow copy operation; no additional arguments are passed. The latter is called to implement the deep copy operation; it is passed one argument, the memo dictionary. If the `__deepcopy__()` implementation needs to make a deep copy of a component, it should call the `deepcopy()` function with the component as first argument and the memo dictionary as second argument.

**See Also:**

**Module** `pickle` Discussion of the special methods used to support object state retrieval and restoration.

## 8.18 pprint — Data pretty printer

**Source code:** `Lib/pprint.py`

---

The `pprint` module provides a capability to “pretty-print” arbitrary Python data structures in a form which can be used as input to the interpreter. If the formatted structures include objects which are not fundamental Python types, the representation may not be loadable. This may be the case if objects such as files, sockets, classes, or instances are included, as well as many other built-in objects which are not representable as Python constants.

The formatted representation keeps objects on a single line if it can, and breaks them onto multiple lines if they don't fit within the allowed width. Construct `PrettyPrinter` objects explicitly if you need to adjust the width constraint.

Changed in version 2.5: Dictionaries are sorted by key before the display is computed; before 2.5, a dictionary was sorted only if its display required more than one line, although that wasn't documented. Changed in version 2.6: Added support for `set` and `frozenset`. The `pprint` module defines one class:

**class** `pprint.PrettyPrinter(...)`

Construct a `PrettyPrinter` instance. This constructor understands several keyword parameters. An output stream may be set using the `stream` keyword; the only method used on the stream object is the file protocol's `write()` method. If not specified, the `PrettyPrinter` adopts `sys.stdout`. Three additional parameters may be used to control the formatted representation. The keywords are `indent`, `depth`, and `width`. The amount of indentation added for each recursive level is specified by `indent`; the default is one. Other values can cause output to look a little odd, but can make nesting easier to spot. The number of levels which may be printed is controlled by `depth`; if the data structure being printed is too deep, the next contained level is replaced by `...`. By default, there is no constraint on the depth of the objects being formatted. The desired output width is constrained using the `width` parameter; the default is 80 characters. If a structure cannot be formatted within the constrained width, a best effort will be made.

```
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> stuff.insert(0, stuff[:])
>>> pp = pprint.PrettyPrinter(indent=4)
>>> pp.pprint(stuff)
[ ['spam', 'eggs', 'lumberjack', 'knights', 'ni'],
  'spam',
  'eggs',
  'lumberjack',
  'knights',
  'ni']
>>> tup = ('spam', ('eggs', ('lumberjack', ('knights', ('ni', ('dead',
... ('parrot', ('fresh fruit',))))))))))
>>> pp = pprint.PrettyPrinter(depth=6)
>>> pp.pprint(tup)
('spam', ('eggs', ('lumberjack', ('knights', ('ni', ('dead', (...)))))))
```

The `PrettyPrinter` class supports several derivative functions:

`pprint.pformat(object[, indent[, width[, depth]]])`

Return the formatted representation of `object` as a string. `indent`, `width` and `depth` will be passed to the `PrettyPrinter` constructor as formatting parameters. Changed in version 2.4: The parameters `indent`, `width` and `depth` were added.

`pprint.pprint(object[, stream[, indent[, width[, depth]]]])`

Prints the formatted representation of `object` on `stream`, followed by a newline. If `stream` is omitted, `sys.stdout` is used. This may be used in the interactive interpreter instead of a `print` statement for inspecting values. `indent`, `width` and `depth` will be passed to the `PrettyPrinter` constructor as formatting parameters.

```
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> stuff.insert(0, stuff)
>>> pprint.pprint(stuff)
[<Recursion on list with id=...>,
  'spam',
  'eggs',
  'lumberjack',
  'knights',
```

```
'ni']
```

Changed in version 2.4: The parameters *indent*, *width* and *depth* were added.

`pprint.isreadable(object)`

Determine if the formatted representation of *object* is “readable,” or can be used to reconstruct the value using `eval()`. This always returns `False` for recursive objects.

```
>>> pprint.isreadable(stuff)
False
```

`pprint.isrecursive(object)`

Determine if *object* requires a recursive representation.

One more support function is also defined:

`pprint.saferepr(object)`

Return a string representation of *object*, protected against recursive data structures. If the representation of *object* exposes a recursive entry, the recursive reference will be represented as `<Recursion on typename with id=number>`. The representation is not otherwise formatted.

```
>>> pprint.saferepr(stuff)
"[<Recursion on list with id=...>, 'spam', 'eggs', 'lumberjack', 'knights', 'ni']"
```

### 8.18.1 PrettyPrinter Objects

`PrettyPrinter` instances have the following methods:

`PrettyPrinter.pformat(object)`

Return the formatted representation of *object*. This takes into account the options passed to the `PrettyPrinter` constructor.

`PrettyPrinter.pprint(object)`

Print the formatted representation of *object* on the configured stream, followed by a newline.

The following methods provide the implementations for the corresponding functions of the same names. Using these methods on an instance is slightly more efficient since new `PrettyPrinter` objects don't need to be created.

`PrettyPrinter.isreadable(object)`

Determine if the formatted representation of the object is “readable,” or can be used to reconstruct the value using `eval()`. Note that this returns `False` for recursive objects. If the *depth* parameter of the `PrettyPrinter` is set and the object is deeper than allowed, this returns `False`.

`PrettyPrinter.isrecursive(object)`

Determine if the object requires a recursive representation.

This method is provided as a hook to allow subclasses to modify the way objects are converted to strings. The default implementation uses the internals of the `saferepr()` implementation.

`PrettyPrinter.format(object, context, maxlevels, level)`

Returns three values: the formatted version of *object* as a string, a flag indicating whether the result is readable, and a flag indicating whether recursion was detected. The first argument is the object to be presented. The second is a dictionary which contains the `id()` of objects that are part of the current presentation context (direct and indirect containers for *object* that are affecting the presentation) as the keys; if an object needs to be presented which is already represented in *context*, the third return value should be `True`. Recursive calls to the `format()` method should add additional entries for containers to this dictionary. The third argument, *maxlevels*, gives the requested limit to recursion; this will be 0 if there is no requested limit. This argument

should be passed unmodified to recursive calls. The fourth argument, *level*, gives the current level; recursive calls should be passed a value less than that of the current call. New in version 2.3.

## 8.18.2 pprint Example

This example demonstrates several uses of the `pprint()` function and its parameters.

```
>>> import pprint
>>> tup = ('spam', ('eggs', ('lumberjack', ('knights', ('ni', ('dead',
... ('parrot', ('fresh fruit',))))))))
>>> stuff = ['a' * 10, tup, ['a' * 30, 'b' * 30], ['c' * 20, 'd' * 20]]
>>> pprint.pprint(stuff)
['aaaaaaaaaa',
 ('spam',
  ('eggs',
   ('lumberjack',
    ('knights', ('ni', ('dead', ('parrot', ('fresh fruit',))))))),
 ['aaaaaaaaaaaaaaaaaaaaaaaaaaaaaa', 'bbbbbbbbbbbbbbbbbbbbbbbbbbbbbb'],
 ['cccccccccccccccccccc', 'dddddddddddddddddd']]
>>> pprint.pprint(stuff, depth=3)
['aaaaaaaaaa',
 ('spam', ('eggs', (...))),
 ['aaaaaaaaaaaaaaaaaaaaaaaaaaaaaa', 'bbbbbbbbbbbbbbbbbbbbbbbbbbbbbb'],
 ['cccccccccccccccccccc', 'dddddddddddddddddd']]
>>> pprint.pprint(stuff, width=60)
['aaaaaaaaaa',
 ('spam',
  ('eggs',
   ('lumberjack',
    ('knights',
     ('ni', ('dead', ('parrot', ('fresh fruit',))))))),
 ['aaaaaaaaaaaaaaaaaaaaaaaaaaaaaa',
  'bbbbbbbbbbbbbbbbbbbbbbbbbbbbbb'],
 ['cccccccccccccccccccc', 'dddddddddddddddddd']]
```

## 8.19 repr — Alternate repr() implementation

**Note:** The `repr` module has been renamed to `reprlib` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

**Source code:** [Lib/repr.py](#)

The `repr` module provides a means for producing object representations with limits on the size of the resulting strings. This is used in the Python debugger and may be useful in other contexts as well.

This module provides a class, an instance, and a function:

**class** `repr.Repr`

Class which provides formatting services useful in implementing functions similar to the built-in `repr()`; size limits for different object types are added to avoid the generation of representations which are excessively long.

`repr.aRepr`

This is an instance of `Repr` which is used to provide the `repr()` function described below. Changing the attributes of this object will affect the size limits used by `repr()` and the Python debugger.

`repr.repr(obj)`

This is the `repr()` method of `aRepr`. It returns a string similar to that returned by the built-in function of the same name, but with limits on most sizes.

## 8.19.1 Repr Objects

`Repr` instances provide several attributes which can be used to provide size limits for the representations of different object types, and methods which format specific object types.

`Repr.maxlevel`

Depth limit on the creation of recursive representations. The default is 6.

`Repr.maxdict`

`Repr.maxlist`

`Repr.maxtuple`

`Repr.maxset`

`Repr.maxfrozenset`

`Repr.maxdeque`

`Repr.maxarray`

Limits on the number of entries represented for the named object type. The default is 4 for `maxdict`, 5 for `maxarray`, and 6 for the others. New in version 2.4: `maxset`, `maxfrozenset`, and `set`.

`Repr.maxlong`

Maximum number of characters in the representation for a long integer. Digits are dropped from the middle. The default is 40.

`Repr.maxstring`

Limit on the number of characters in the representation of the string. Note that the “normal” representation of the string is used as the character source: if escape sequences are needed in the representation, these may be mangled when the representation is shortened. The default is 30.

`Repr.maxother`

This limit is used to control the size of object types for which no specific formatting method is available on the `Repr` object. It is applied in a similar manner as `maxstring`. The default is 20.

`Repr.repr(obj)`

The equivalent to the built-in `repr()` that uses the formatting imposed by the instance.

`Repr.repr1(obj, level)`

Recursive implementation used by `repr()`. This uses the type of `obj` to determine which formatting method to call, passing it `obj` and `level`. The type-specific methods should call `repr1()` to perform recursive formatting, with `level - 1` for the value of `level` in the recursive call.

`Repr.repr_TYPE(obj, level)`

Formatting methods for specific types are implemented as methods with a name based on the type name. In the method name, `TYPE` is replaced by `string.join(string.split(type(obj).__name__, '_'))`. Dispatch to these methods is handled by `repr1()`. Type-specific methods which need to recursively format a value should call `self.repr1(subobj, level - 1)`.

## 8.19.2 Subclassing Repr Objects

The use of dynamic dispatching by `Repr.repr1()` allows subclasses of `Repr` to add support for additional built-in object types or to modify the handling of types already supported. This example shows how special support for file

objects could be added:

```
import repr as reprlib
import sys

class MyRepr(reprlib.Repr):
    def repr_file(self, obj, level):
        if obj.name in ['<stdin>', '<stdout>', '<stderr>']:
            return obj.name
        else:
            return repr(obj)

aRepr = MyRepr()
print aRepr.repr(sys.stdin)           # prints '<stdin>'
```



# NUMERIC AND MATHEMATICAL MODULES

The modules described in this chapter provide numeric and math-related functions and data types. The `numbers` module defines an abstract hierarchy of numeric types. The `math` and `cmath` modules contain various mathematical functions for floating-point and complex numbers. For users more interested in decimal accuracy than in speed, the `decimal` module supports exact representations of decimal numbers.

The following modules are documented in this chapter:

## 9.1 `numbers` — Numeric abstract base classes

New in version 2.6. The `numbers` module ( [PEP 3141](#) ) defines a hierarchy of numeric *abstract base classes* which progressively define more operations. None of the types defined in this module can be instantiated.

### **class** `numbers.Number`

The root of the numeric hierarchy. If you just want to check if an argument `x` is a number, without caring what kind, use `isinstance(x, Number)`.

### 9.1.1 The numeric tower

#### **class** `numbers.Complex`

Subclasses of this type describe complex numbers and include the operations that work on the built-in `complex` type. These are: conversions to `complex` and `bool`, `real`, `imag`, `+`, `-`, `*`, `/`, `abs()`, `conjugate()`, `==`, and `!=`. All except `-` and `!=` are abstract.

#### **real**

Abstract. Retrieves the real component of this number.

#### **imag**

Abstract. Retrieves the imaginary component of this number.

#### **conjugate()**

Abstract. Returns the complex conjugate. For example, `(1+3j).conjugate() == (1-3j)`.

#### **class** `numbers.Real`

To `Complex`, `Real` adds the operations that work on real numbers.

In short, those are: a conversion to `float`, `math.trunc()`, `round()`, `math.floor()`, `math.ceil()`, `divmod()`, `//`, `%`, `<`, `<=`, `>`, and `>=`.

`Real` also provides defaults for `complex()`, `real`, `imag`, and `conjugate()`.

**class** `numbers.Rational`

Subtypes `Real` and adds `numerator` and `denominator` properties, which should be in lowest terms. With these, it provides a default for `float()`.

**numerator**  
Abstract.

**denominator**  
Abstract.

**class** `numbers.Integral`

Subtypes `Rational` and adds a conversion to `int`. Provides defaults for `float()`, `numerator`, and `denominator`, and bit-string operations: `<<`, `>>`, `&`, `^`, `|`, `~`.

## 9.1.2 Notes for type implementors

Implementors should be careful to make equal numbers equal and hash them to the same values. This may be subtle if there are two different extensions of the real numbers. For example, `fractions.Fraction` implements `hash()` as follows:

```
def __hash__(self):
    if self.denominator == 1:
        # Get integers right.
        return hash(self.numerator)
    # Expensive check, but definitely correct.
    if self == float(self):
        return hash(float(self))
    else:
        # Use tuple's hash to avoid a high collision rate on
        # simple fractions.
        return hash((self.numerator, self.denominator))
```

### Adding More Numeric ABCs

There are, of course, more possible ABCs for numbers, and this would be a poor hierarchy if it precluded the possibility of adding those. You can add `MyFoo` between `Complex` and `Real` with:

```
class MyFoo(Complex): ...
MyFoo.register(Real)
```

### Implementing the arithmetic operations

We want to implement the arithmetic operations so that mixed-mode operations either call an implementation whose author knew about the types of both arguments, or convert both to the nearest built in type and do the operation there. For subtypes of `Integral`, this means that `__add__()` and `__radd__()` should be defined as:

```
class MyIntegral(Integral):

    def __add__(self, other):
        if isinstance(other, MyIntegral):
            return do_my_adding_stuff(self, other)
        elif isinstance(other, OtherTypeIKnowAbout):
            return do_my_other_adding_stuff(self, other)
        else:
            return NotImplemented
```

```

def __radd__(self, other):
    if isinstance(other, MyIntegral):
        return do_my_adding_stuff(other, self)
    elif isinstance(other, OtherTypeIKnowAbout):
        return do_my_other_adding_stuff(other, self)
    elif isinstance(other, Integral):
        return int(other) + int(self)
    elif isinstance(other, Real):
        return float(other) + float(self)
    elif isinstance(other, Complex):
        return complex(other) + complex(self)
    else:
        return NotImplemented

```

There are 5 different cases for a mixed-type operation on subclasses of `Complex`. I'll refer to all of the above code that doesn't refer to `MyIntegral` and `OtherTypeIKnowAbout` as “boilerplate”. `a` will be an instance of `A`, which is a subtype of `Complex` (`a : A <: Complex`), and `b : B <: Complex`. I'll consider `a + b`:

1. If `A` defines an `__add__()` which accepts `b`, all is well.
2. If `A` falls back to the boilerplate code, and it were to return a value from `__add__()`, we'd miss the possibility that `B` defines a more intelligent `__radd__()`, so the boilerplate should return `NotImplemented` from `__add__()`. (Or `A` may not implement `__add__()` at all.)
3. Then `B`'s `__radd__()` gets a chance. If it accepts `a`, all is well.
4. If it falls back to the boilerplate, there are no more possible methods to try, so this is where the default implementation should live.
5. If `B <: A`, Python tries `B.__radd__` before `A.__add__`. This is ok, because it was implemented with knowledge of `A`, so it can handle those instances before delegating to `Complex`.

If `A <: Complex` and `B <: Real` without sharing any other knowledge, then the appropriate shared operation is the one involving the built in `complex`, and both `__radd__()` s land there, so `a+b == b+a`.

Because most of the operations on any given type will be very similar, it can be useful to define a helper function which generates the forward and reverse instances of any given operator. For example, `fractions.Fraction` uses:

```

def _operator_fallbacks(monomorphic_operator, fallback_operator):
    def forward(a, b):
        if isinstance(b, (int, long, Fraction)):
            return monomorphic_operator(a, b)
        elif isinstance(b, float):
            return fallback_operator(float(a), b)
        elif isinstance(b, complex):
            return fallback_operator(complex(a), b)
        else:
            return NotImplemented
    forward.__name__ = '__' + fallback_operator.__name__ + '__'
    forward.__doc__ = monomorphic_operator.__doc__

    def reverse(b, a):
        if isinstance(a, Rational):
            # Includes ints.
            return monomorphic_operator(a, b)
        elif isinstance(a, numbers.Real):
            return fallback_operator(float(a), float(b))

```

```
    elif isinstance(a, numbers.Complex):
        return fallback_operator(complex(a), complex(b))
    else:
        return NotImplemented
reverse.__name__ = '__r' + fallback_operator.__name__ + '__'
reverse.__doc__ = monomorphic_operator.__doc__

return forward, reverse

def _add(a, b):
    """a + b"""
    return Fraction(a.numerator * b.denominator +
                    b.numerator * a.denominator,
                    a.denominator * b.denominator)

__add__, __radd__ = _operator_fallbacks(_add, operator.add)

# ...
```

## 9.2 math — Mathematical functions

This module is always available. It provides access to the mathematical functions defined by the C standard.

These functions cannot be used with complex numbers; use the functions of the same name from the `cmath` module if you require support for complex numbers. The distinction between functions which support complex numbers and those which don't is made since most users do not want to learn quite as much mathematics as required to understand complex numbers. Receiving an exception instead of a complex result allows earlier detection of the unexpected complex number used as a parameter, so that the programmer can determine how and why it was generated in the first place.

The following functions are provided by this module. Except when explicitly noted otherwise, all return values are floats.

### 9.2.1 Number-theoretic and representation functions

`math.ceil(x)`

Return the ceiling of  $x$  as a float, the smallest integer value greater than or equal to  $x$ .

`math.copysign(x, y)`

Return  $x$  with the sign of  $y$ . On a platform that supports signed zeros, `copysign(1.0, -0.0)` returns `-1.0`. New in version 2.6.

`math.fabs(x)`

Return the absolute value of  $x$ .

`math.factorial(x)`

Return  $x$  factorial. Raises `ValueError` if  $x$  is not integral or is negative. New in version 2.6.

`math.floor(x)`

Return the floor of  $x$  as a float, the largest integer value less than or equal to  $x$ .

`math.fmod(x, y)`

Return `fmod(x, y)`, as defined by the platform C library. Note that the Python expression `x % y` may not return the same result. The intent of the C standard is that `fmod(x, y)` be exactly (mathematically; to infinite precision) equal to  $x - n*y$  for some integer  $n$  such that the result has the same sign as  $x$  and magnitude less

than `abs(y)`. Python's `x % y` returns a result with the sign of `y` instead, and may not be exactly computable for float arguments. For example, `fmod(-1e-100, 1e100)` is `-1e-100`, but the result of Python's `-1e-100 % 1e100` is `1e100-1e-100`, which cannot be represented exactly as a float, and rounds to the surprising `1e100`. For this reason, function `fmod()` is generally preferred when working with floats, while Python's `x % y` is preferred when working with integers.

`math.frexp(x)`

Return the mantissa and exponent of `x` as the pair `(m, e)`. `m` is a float and `e` is an integer such that `x == m * 2**e` exactly. If `x` is zero, returns `(0.0, 0)`, otherwise `0.5 <= abs(m) < 1`. This is used to “pick apart” the internal representation of a float in a portable way.

`math.fsum(iterable)`

Return an accurate floating point sum of values in the iterable. Avoids loss of precision by tracking multiple intermediate partial sums:

```
>>> sum([.1, .1, .1, .1, .1, .1, .1, .1, .1, .1])
0.9999999999999999
>>> fsum([.1, .1, .1, .1, .1, .1, .1, .1, .1, .1])
1.0
```

The algorithm's accuracy depends on IEEE-754 arithmetic guarantees and the typical case where the rounding mode is half-even. On some non-Windows builds, the underlying C library uses extended precision addition and may occasionally double-round an intermediate sum causing it to be off in its least significant bit.

For further discussion and two alternative approaches, see the [ASPN cookbook recipes for accurate floating point summation](#). New in version 2.6.

`math.isinf(x)`

Check if the float `x` is positive or negative infinity. New in version 2.6.

`math.isnan(x)`

Check if the float `x` is a NaN (not a number). For more information on NaNs, see the IEEE 754 standards. New in version 2.6.

`math.ldexp(x, i)`

Return `x * (2**i)`. This is essentially the inverse of function `frexp()`.

`math.modf(x)`

Return the fractional and integer parts of `x`. Both results carry the sign of `x` and are floats.

`math.trunc(x)`

Return the Real value `x` truncated to an Integral (usually a long integer). Uses the `__trunc__` method. New in version 2.6.

Note that `frexp()` and `modf()` have a different call/return pattern than their C equivalents: they take a single argument and return a pair of values, rather than returning their second return value through an ‘output parameter’ (there is no such thing in Python).

For the `ceil()`, `floor()`, and `modf()` functions, note that *all* floating-point numbers of sufficiently large magnitude are exact integers. Python floats typically carry no more than 53 bits of precision (the same as the platform C double type), in which case any float `x` with `abs(x) >= 2**52` necessarily has no fractional bits.

## 9.2.2 Power and logarithmic functions

`math.exp(x)`

Return `e**x`.

`math.expml(x)`

Return  $e^{**x} - 1$ . For small floats  $x$ , the subtraction in  $\exp(x) - 1$  can result in a significant loss of precision; the `expml()` function provides a way to compute this quantity to full precision:

```
>>> from math import exp, expml
>>> exp(1e-5) - 1 # gives result accurate to 11 places
1.0000050000069649e-05
>>> expml(1e-5) # result accurate to full precision
1.0000050000166668e-05
```

New in version 2.7.

`math.log(x[, base])`

With one argument, return the natural logarithm of  $x$  (to base  $e$ ).

With two arguments, return the logarithm of  $x$  to the given *base*, calculated as  $\log(x) / \log(\text{base})$ . Changed in version 2.3: *base* argument added.

`math.log1p(x)`

Return the natural logarithm of  $1+x$  (base  $e$ ). The result is calculated in a way which is accurate for  $x$  near zero. New in version 2.6.

`math.log10(x)`

Return the base-10 logarithm of  $x$ . This is usually more accurate than `log(x, 10)`.

`math.pow(x, y)`

Return  $x$  raised to the power  $y$ . Exceptional cases follow Annex 'F' of the C99 standard as far as possible. In particular, `pow(1.0, x)` and `pow(x, 0.0)` always return `1.0`, even when  $x$  is a zero or a NaN. If both  $x$  and  $y$  are finite,  $x$  is negative, and  $y$  is not an integer then `pow(x, y)` is undefined, and raises `ValueError`. Changed in version 2.6: The outcome of `1**nan` and `nan**0` was undefined.

`math.sqrt(x)`

Return the square root of  $x$ .

## 9.2.3 Trigonometric functions

`math.acos(x)`

Return the arc cosine of  $x$ , in radians.

`math.asin(x)`

Return the arc sine of  $x$ , in radians.

`math.atan(x)`

Return the arc tangent of  $x$ , in radians.

`math.atan2(y, x)`

Return `atan(y / x)`, in radians. The result is between  $-\pi$  and  $\pi$ . The vector in the plane from the origin to point  $(x, y)$  makes this angle with the positive X axis. The point of `atan2()` is that the signs of both inputs are known to it, so it can compute the correct quadrant for the angle. For example, `atan(1)` and `atan2(1, 1)` are both  $\pi/4$ , but `atan2(-1, -1)` is  $-3\pi/4$ .

`math.cos(x)`

Return the cosine of  $x$  radians.

`math.hypot(x, y)`

Return the Euclidean norm, `sqrt(x*x + y*y)`. This is the length of the vector from the origin to point  $(x, y)$ .

`math.sin(x)`  
Return the sine of  $x$  radians.

`math.tan(x)`  
Return the tangent of  $x$  radians.

## 9.2.4 Angular conversion

`math.degrees(x)`  
Converts angle  $x$  from radians to degrees.

`math.radians(x)`  
Converts angle  $x$  from degrees to radians.

## 9.2.5 Hyperbolic functions

`math.acosh(x)`  
Return the inverse hyperbolic cosine of  $x$ . New in version 2.6.

`math.asinh(x)`  
Return the inverse hyperbolic sine of  $x$ . New in version 2.6.

`math.atanh(x)`  
Return the inverse hyperbolic tangent of  $x$ . New in version 2.6.

`math.cosh(x)`  
Return the hyperbolic cosine of  $x$ .

`math.sinh(x)`  
Return the hyperbolic sine of  $x$ .

`math.tanh(x)`  
Return the hyperbolic tangent of  $x$ .

## 9.2.6 Special functions

`math.erf(x)`  
Return the error function at  $x$ . New in version 2.7.

`math.erfc(x)`  
Return the complementary error function at  $x$ . New in version 2.7.

`math.gamma(x)`  
Return the Gamma function at  $x$ . New in version 2.7.

`math.lgamma(x)`  
Return the natural logarithm of the absolute value of the Gamma function at  $x$ . New in version 2.7.

## 9.2.7 Constants

`math.pi`  
The mathematical constant  $\pi = 3.141592\dots$ , to available precision.

`math.e`  
The mathematical constant  $e = 2.718281\dots$ , to available precision.

**CPython implementation detail:** The `math` module consists mostly of thin wrappers around the platform C math library functions. Behavior in exceptional cases follows Annex F of the C99 standard where appropriate. The current implementation will raise `ValueError` for invalid operations like `sqrt(-1.0)` or `log(0.0)` (where C99 Annex F recommends signaling invalid operation or divide-by-zero), and `OverflowError` for results that overflow (for example, `exp(1000.0)`). A NaN will not be returned from any of the functions above unless one or more of the input arguments was a NaN; in that case, most functions will return a NaN, but (again following C99 Annex F) there are some exceptions to this rule, for example `pow(float('nan'), 0.0)` or `hypot(float('nan'), float('inf'))`.

Note that Python makes no effort to distinguish signaling NaNs from quiet NaNs, and behavior for signaling NaNs remains unspecified. Typical behavior is to treat all NaNs as though they were quiet. Changed in version 2.6: Behavior in special cases now aims to follow C99 Annex F. In earlier versions of Python the behavior in special cases was loosely specified.

**See Also:**

**Module `cmath`** Complex number versions of many of these functions.

## 9.3 `cmath` — Mathematical functions for complex numbers

This module is always available. It provides access to mathematical functions for complex numbers. The functions in this module accept integers, floating-point numbers or complex numbers as arguments. They will also accept any Python object that has either a `__complex__()` or a `__float__()` method: these methods are used to convert the object to a complex or floating-point number, respectively, and the function is then applied to the result of the conversion.

---

**Note:** On platforms with hardware and system-level support for signed zeros, functions involving branch cuts are continuous on *both* sides of the branch cut: the sign of the zero distinguishes one side of the branch cut from the other. On platforms that do not support signed zeros the continuity is as specified below.

---

### 9.3.1 Conversions to and from polar coordinates

A Python complex number `z` is stored internally using *rectangular* or *Cartesian* coordinates. It is completely determined by its *real part* `z.real` and its *imaginary part* `z.imag`. In other words:

```
z == z.real + z.imag*1j
```

*Polar coordinates* give an alternative way to represent a complex number. In polar coordinates, a complex number `z` is defined by the modulus `r` and the phase angle `phi`. The modulus `r` is the distance from `z` to the origin, while the phase `phi` is the counterclockwise angle, measured in radians, from the positive x-axis to the line segment that joins the origin to `z`.

The following functions can be used to convert from the native rectangular coordinates to polar coordinates and back.

`cmath.phase(x)`

Return the phase of `x` (also known as the *argument* of `x`), as a float. `phase(x)` is equivalent to `math.atan2(x.imag, x.real)`. The result lies in the range  $[-\pi, \pi]$ , and the branch cut for this operation lies along the negative real axis, continuous from above. On systems with support for signed zeros (which includes most systems in current use), this means that the sign of the result is the same as the sign of `x.imag`, even when `x.imag` is zero:

```
>>> phase(complex(-1.0, 0.0))
3.1415926535897931
```

```
>>> phase(complex(-1.0, -0.0))
-3.1415926535897931
```

New in version 2.6.

---

**Note:** The modulus (absolute value) of a complex number  $x$  can be computed using the built-in `abs()` function. There is no separate `cmath` module function for this operation.

---

`cmath.polar`( $x$ )

Return the representation of  $x$  in polar coordinates. Returns a pair ( $r$ ,  $\phi$ ) where  $r$  is the modulus of  $x$  and  $\phi$  is the phase of  $x$ . `polar(x)` is equivalent to `(abs(x), phase(x))`. New in version 2.6.

`cmath.rect`( $r$ ,  $\phi$ )

Return the complex number  $x$  with polar coordinates  $r$  and  $\phi$ . Equivalent to  $r * (\text{math.cos}(\phi) + \text{math.sin}(\phi) * 1j)$ . New in version 2.6.

### 9.3.2 Power and logarithmic functions

`cmath.exp`( $x$ )

Return the exponential value  $e^{**x}$ .

`cmath.log`( $x$ [,  $base$ ])

Returns the logarithm of  $x$  to the given  $base$ . If the  $base$  is not specified, returns the natural logarithm of  $x$ . There is one branch cut, from 0 along the negative real axis to  $-\infty$ , continuous from above. Changed in version 2.4:  $base$  argument added.

`cmath.log10`( $x$ )

Return the base-10 logarithm of  $x$ . This has the same branch cut as `log()`.

`cmath.sqrt`( $x$ )

Return the square root of  $x$ . This has the same branch cut as `log()`.

### 9.3.3 Trigonometric functions

`cmath.acos`( $x$ )

Return the arc cosine of  $x$ . There are two branch cuts: One extends right from 1 along the real axis to  $\infty$ , continuous from below. The other extends left from -1 along the real axis to  $-\infty$ , continuous from above.

`cmath.asin`( $x$ )

Return the arc sine of  $x$ . This has the same branch cuts as `acos()`.

`cmath.atan`( $x$ )

Return the arc tangent of  $x$ . There are two branch cuts: One extends from  $1j$  along the imaginary axis to  $\infty j$ , continuous from the right. The other extends from  $-1j$  along the imaginary axis to  $-\infty j$ , continuous from the left. Changed in version 2.6: direction of continuity of upper cut reversed

`cmath.cos`( $x$ )

Return the cosine of  $x$ .

`cmath.sin`( $x$ )

Return the sine of  $x$ .

`cmath.tan`( $x$ )

Return the tangent of  $x$ .

### 9.3.4 Hyperbolic functions

`cmath.acosh`(*x*)

Return the hyperbolic arc cosine of *x*. There is one branch cut, extending left from 1 along the real axis to  $-\infty$ , continuous from above.

`cmath.asinh`(*x*)

Return the hyperbolic arc sine of *x*. There are two branch cuts: One extends from  $1j$  along the imaginary axis to  $\infty j$ , continuous from the right. The other extends from  $-1j$  along the imaginary axis to  $-\infty j$ , continuous from the left. Changed in version 2.6: branch cuts moved to match those recommended by the C99 standard

`cmath.atanh`(*x*)

Return the hyperbolic arc tangent of *x*. There are two branch cuts: One extends from 1 along the real axis to  $\infty$ , continuous from below. The other extends from  $-1$  along the real axis to  $-\infty$ , continuous from above. Changed in version 2.6: direction of continuity of right cut reversed

`cmath.cosh`(*x*)

Return the hyperbolic cosine of *x*.

`cmath.sinh`(*x*)

Return the hyperbolic sine of *x*.

`cmath.tanh`(*x*)

Return the hyperbolic tangent of *x*.

### 9.3.5 Classification functions

`cmath.isinf`(*x*)

Return *True* if the real or the imaginary part of *x* is positive or negative infinity. New in version 2.6.

`cmath.isnan`(*x*)

Return *True* if the real or imaginary part of *x* is not a number (NaN). New in version 2.6.

### 9.3.6 Constants

`cmath.pi`

The mathematical constant  $\pi$ , as a float.

`cmath.e`

The mathematical constant *e*, as a float.

Note that the selection of functions is similar, but not identical, to that in module `math`. The reason for having two modules is that some users aren't interested in complex numbers, and perhaps don't even know what they are. They would rather have `math.sqrt(-1)` raise an exception than return a complex number. Also note that the functions defined in `cmath` always return a complex number, even if the answer can be expressed as a real number (in which case the complex number has an imaginary part of zero).

A note on branch cuts: They are curves along which the given function fails to be continuous. They are a necessary feature of many complex functions. It is assumed that if you need to compute with complex functions, you will understand about branch cuts. Consult almost any (not too elementary) book on complex variables for enlightenment. For information of the proper choice of branch cuts for numerical purposes, a good reference should be the following:

**See Also:**

Kahan, W: Branch cuts for complex elementary functions; or, Much ado about nothing's sign bit. In Iserles, A., and Powell, M. (eds.), The state of the art in numerical analysis. Clarendon Press (1987) pp165-211.

## 9.4 decimal — Decimal fixed point and floating point arithmetic

New in version 2.4. The `decimal` module provides support for decimal floating point arithmetic. It offers several advantages over the `float` datatype:

- Decimal “is based on a floating-point model which was designed with people in mind, and necessarily has a paramount guiding principle – computers must provide an arithmetic that works in the same way as the arithmetic that people learn at school.” – excerpt from the decimal arithmetic specification.
- Decimal numbers can be represented exactly. In contrast, numbers like 1.1 and 2.2 do not have exact representations in binary floating point. End users typically would not expect  $1.1 + 2.2$  to display as `3.3000000000000003` as it does with binary floating point.
- The exactness carries over into arithmetic. In decimal floating point,  $0.1 + 0.1 + 0.1 - 0.3$  is exactly equal to zero. In binary floating point, the result is `5.5511151231257827e-017`. While near to zero, the differences prevent reliable equality testing and differences can accumulate. For this reason, decimal is preferred in accounting applications which have strict equality invariants.
- The decimal module incorporates a notion of significant places so that  $1.30 + 1.20$  is `2.50`. The trailing zero is kept to indicate significance. This is the customary presentation for monetary applications. For multiplication, the “schoolbook” approach uses all the figures in the multiplicands. For instance,  $1.3 * 1.2$  gives `1.56` while  $1.30 * 1.20$  gives `1.5600`.
- Unlike hardware based binary floating point, the decimal module has a user alterable precision (defaulting to 28 places) which can be as large as needed for a given problem:

```
>>> from decimal import *
>>> getcontext().prec = 6
>>> Decimal(1) / Decimal(7)
Decimal('0.142857')
>>> getcontext().prec = 28
>>> Decimal(1) / Decimal(7)
Decimal('0.1428571428571428571428571429')
```

- Both binary and decimal floating point are implemented in terms of published standards. While the built-in float type exposes only a modest portion of its capabilities, the decimal module exposes all required parts of the standard. When needed, the programmer has full control over rounding and signal handling. This includes an option to enforce exact arithmetic by using exceptions to block any inexact operations.
- The decimal module was designed to support “without prejudice, both exact unrounded decimal arithmetic (sometimes called fixed-point arithmetic) and rounded floating-point arithmetic.” – excerpt from the decimal arithmetic specification.

The module design is centered around three concepts: the decimal number, the context for arithmetic, and signals.

A decimal number is immutable. It has a sign, coefficient digits, and an exponent. To preserve significance, the coefficient digits do not truncate trailing zeros. Decimals also include special values such as `Infinity`, `-Infinity`, and `NaN`. The standard also differentiates `-0` from `+0`.

The context for arithmetic is an environment specifying precision, rounding rules, limits on exponents, flags indicating the results of operations, and trap enablers which determine whether signals are treated as exceptions. Rounding options include `ROUND_CEILING`, `ROUND_DOWN`, `ROUND_FLOOR`, `ROUND_HALF_DOWN`, `ROUND_HALF_EVEN`, `ROUND_HALF_UP`, `ROUND_UP`, and `ROUND_05UP`.

Signals are groups of exceptional conditions arising during the course of computation. Depending on the needs of the application, signals may be ignored, considered as informational, or treated as exceptions. The signals in the decimal module are: `Clamped`, `InvalidOperation`, `DivisionByZero`, `Inexact`, `Rounded`, `Subnormal`, `Overflow`, and `Underflow`.

For each signal there is a flag and a trap enabler. When a signal is encountered, its flag is set to one, then, if the trap enabler is set to one, an exception is raised. Flags are sticky, so the user needs to reset them before monitoring a calculation.

### See Also:

- IBM's General Decimal Arithmetic Specification, [The General Decimal Arithmetic Specification](#).
- IEEE standard 854-1987, [Unofficial IEEE 854 Text](#).

## 9.4.1 Quick-start Tutorial

The usual start to using decimals is importing the module, viewing the current context with `getcontext()` and, if necessary, setting new values for precision, rounding, or enabled traps:

```
>>> from decimal import *
>>> getcontext()
Context(prec=28, rounding=ROUND_HALF_EVEN, Emin=-999999999, Emax=999999999,
        capitals=1, flags=[], traps=[Overflow, DivisionByZero,
        InvalidOperation])

>>> getcontext().prec = 7           # Set a new precision
```

Decimal instances can be constructed from integers, strings, floats, or tuples. Construction from an integer or a float performs an exact conversion of the value of that integer or float. Decimal numbers include special values such as NaN which stands for “Not a number”, positive and negative Infinity, and  $-0$ .

```
>>> getcontext().prec = 28
>>> Decimal(10)
Decimal('10')
>>> Decimal('3.14')
Decimal('3.14')
>>> Decimal(3.14)
Decimal('3.1400000000000000124344978758017532527446746826171875')
>>> Decimal((0, (3, 1, 4), -2))
Decimal('3.14')
>>> Decimal(str(2.0 ** 0.5))
Decimal('1.41421356237')
>>> Decimal(2) ** Decimal('0.5')
Decimal('1.414213562373095048801688724')
>>> Decimal('NaN')
Decimal('NaN')
>>> Decimal('-Infinity')
Decimal('-Infinity')
```

The significance of a new Decimal is determined solely by the number of digits input. Context precision and rounding only come into play during arithmetic operations.

```
>>> getcontext().prec = 6
>>> Decimal('3.0')
Decimal('3.0')
>>> Decimal('3.1415926535')
Decimal('3.1415926535')
>>> Decimal('3.1415926535') + Decimal('2.7182818285')
Decimal('5.85987')
>>> getcontext().rounding = ROUND_UP
```

```
>>> Decimal('3.1415926535') + Decimal('2.7182818285')
Decimal('5.85988')
```

Decimals interact well with much of the rest of Python. Here is a small decimal floating point flying circus:

```
>>> data = map(Decimal, '1.34 1.87 3.45 2.35 1.00 0.03 9.25'.split())
>>> max(data)
Decimal('9.25')
>>> min(data)
Decimal('0.03')
>>> sorted(data)
[Decimal('0.03'), Decimal('1.00'), Decimal('1.34'), Decimal('1.87'),
 Decimal('2.35'), Decimal('3.45'), Decimal('9.25')]
>>> sum(data)
Decimal('19.29')
>>> a,b,c = data[:3]
>>> str(a)
'1.34'
>>> float(a)
1.34
>>> round(a, 1)      # round() first converts to binary floating point
1.3
>>> int(a)
1
>>> a * 5
Decimal('6.70')
>>> a * b
Decimal('2.5058')
>>> c % a
Decimal('0.77')
```

And some mathematical functions are also available to Decimal:

```
>>> getcontext().prec = 28
>>> Decimal(2).sqrt()
Decimal('1.414213562373095048801688724')
>>> Decimal(1).exp()
Decimal('2.718281828459045235360287471')
>>> Decimal('10').ln()
Decimal('2.302585092994045684017991455')
>>> Decimal('10').log10()
Decimal('1')
```

The `quantize()` method rounds a number to a fixed exponent. This method is useful for monetary applications that often round results to a fixed number of places:

```
>>> Decimal('7.325').quantize(Decimal('.01'), rounding=ROUND_DOWN)
Decimal('7.32')
>>> Decimal('7.325').quantize(Decimal('1.'), rounding=ROUND_UP)
Decimal('8')
```

As shown above, the `getcontext()` function accesses the current context and allows the settings to be changed. This approach meets the needs of most applications.

For more advanced work, it may be useful to create alternate contexts using the `Context()` constructor. To make an alternate active, use the `setcontext()` function.

In accordance with the standard, the `Decimal` module provides two ready to use standard contexts, `BasicContext` and `ExtendedContext`. The former is especially useful for debugging because many of the traps are enabled:

```
>>> myothercontext = Context(prec=60, rounding=ROUND_HALF_DOWN)
>>> setcontext(myothercontext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857142857142857142857142857')

>>> ExtendedContext
Context(prec=9, rounding=ROUND_HALF_EVEN, Emin=-999999999, Emax=999999999,
       capitals=1, flags=[], traps=[])
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857143')
>>> Decimal(42) / Decimal(0)
Decimal('Infinity')

>>> setcontext(BasicContext)
>>> Decimal(42) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#143>", line 1, in -toplevel-
    Decimal(42) / Decimal(0)
DivisionByZero: x / 0
```

Contexts also have signal flags for monitoring exceptional conditions encountered during computations. The flags remain set until explicitly cleared, so it is best to clear the flags before each set of monitored computations by using the `clear_flags()` method.

```
>>> setcontext(ExtendedContext)
>>> getcontext().clear_flags()
>>> Decimal(355) / Decimal(113)
Decimal('3.14159292')
>>> getcontext()
Context(prec=9, rounding=ROUND_HALF_EVEN, Emin=-999999999, Emax=999999999,
       capitals=1, flags=[Rounded, Inexact], traps=[])
```

The `flags` entry shows that the rational approximation to  $\pi$  was rounded (digits beyond the context precision were thrown away) and that the result is inexact (some of the discarded digits were non-zero).

Individual traps are set using the dictionary in the `traps` field of a context:

```
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(0)
Decimal('Infinity')
>>> getcontext().traps[DivisionByZero] = 1
>>> Decimal(1) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#112>", line 1, in -toplevel-
    Decimal(1) / Decimal(0)
DivisionByZero: x / 0
```

Most programs adjust the current context only once, at the beginning of the program. And, in many applications, data is converted to `Decimal` with a single cast inside a loop. With context set and decimals created, the bulk of the program manipulates the data no differently than with other Python numeric types.

## 9.4.2 Decimal objects

**class** `decimal.Decimal` (`[value[, context]]`)

Construct a new `Decimal` object based from *value*.

*value* can be an integer, string, tuple, `float`, or another `Decimal` object. If no *value* is given, returns `Decimal('0')`. If *value* is a string, it should conform to the decimal numeric string syntax after leading and trailing whitespace characters are removed:

```

sign           ::= '+' | '-'
digit          ::= '0' | '1' | '2' | '3' | '4' | '5' | '6' | '7' | '8' | '9'
indicator      ::= 'e' | 'E'
digits         ::= digit [digit]...
decimal-part   ::= digits '.' [digits] | ['.'] digits
exponent-part ::= indicator [sign] digits
infinity       ::= 'Infinity' | 'Inf'
nan            ::= 'NaN' [digits] | 'sNaN' [digits]
numeric-value  ::= decimal-part [exponent-part] | infinity
numeric-string ::= [sign] numeric-value | [sign] nan

```

If *value* is a unicode string then other Unicode decimal digits are also permitted where `digit` appears above. These include decimal digits from various other alphabets (for example, Arabic-Indic and Devanāgarī digits) along with the fullwidth digits `u'\uff10'` through `u'\uff19'`.

If *value* is a `tuple`, it should have three components, a sign (0 for positive or 1 for negative), a `tuple` of digits, and an integer exponent. For example, `Decimal((0, (1, 4, 1, 4), -3))` returns `Decimal('1.414')`.

If *value* is a `float`, the binary floating point value is losslessly converted to its exact decimal equivalent. This conversion can often require 53 or more digits of precision. For example, `Decimal(float('1.1'))` converts to `Decimal('1.1000000000000000088817841970012523233890533447265625')`.

The *context* precision does not affect how many digits are stored. That is determined exclusively by the number of digits in *value*. For example, `Decimal('3.00000')` records all five zeros even if the context precision is only three.

The purpose of the *context* argument is determining what to do if *value* is a malformed string. If the context traps `InvalidOperation`, an exception is raised; otherwise, the constructor returns a new `Decimal` with the value of NaN.

Once constructed, `Decimal` objects are immutable. Changed in version 2.6: leading and trailing whitespace characters are permitted when creating a `Decimal` instance from a string. Changed in version 2.7: The argument to the constructor is now permitted to be a `float` instance. `Decimal` floating point objects share many properties with the other built-in numeric types such as `float` and `int`. All of the usual math operations and special methods apply. Likewise, decimal objects can be copied, pickled, printed, used as dictionary keys, used as set elements, compared, sorted, and coerced to another type (such as `float` or `long`).

`Decimal` objects cannot generally be combined with floats in arithmetic operations: an attempt to add a `Decimal` to a `float`, for example, will raise a `TypeError`. There's one exception to this rule: it's possible to use Python's comparison operators to compare a `float` instance `x` with a `Decimal` instance `y`. Without this exception, comparisons between `Decimal` and `float` instances would follow the general rules for comparing objects of different types described in the *expressions* section of the reference manual, leading to confusing results. Changed in version 2.7: A comparison between a `float` instance `x` and a `Decimal` instance `y` now returns a result based on the values of `x` and `y`. In earlier versions `x < y` returned the same (arbitrary) result for any `Decimal` instance `x` and any `float` instance `y`. In addition to the standard numeric properties, decimal floating point objects also have a number of specialized methods:

**adjusted()**

Return the adjusted exponent after shifting out the coefficient's rightmost digits until only the lead digit remains: `Decimal('321e+5').adjusted()` returns seven. Used for determining the position of the most significant digit with respect to the decimal point.

**as\_tuple()**

Return a *named tuple* representation of the number: `DecimalTuple(sign, digits, exponent)`. Changed in version 2.6: Use a named tuple.

**canonical()**

Return the canonical encoding of the argument. Currently, the encoding of a `Decimal` instance is always canonical, so this operation returns its argument unchanged. New in version 2.6.

**compare(*other*[, *context*])**

Compare the values of two `Decimal` instances. This operation behaves in the same way as the usual comparison method `__cmp__()`, except that `compare()` returns a `Decimal` instance rather than an integer, and if either operand is a NaN then the result is a NaN:

```
a or b is a NaN ==> Decimal('NaN')
a < b           ==> Decimal('-1')
a == b         ==> Decimal('0')
a > b          ==> Decimal('1')
```

**compare\_signal(*other*[, *context*])**

This operation is identical to the `compare()` method, except that all NaNs signal. That is, if neither operand is a signaling NaN then any quiet NaN operand is treated as though it were a signaling NaN. New in version 2.6.

**compare\_total(*other*)**

Compare two operands using their abstract representation rather than their numerical value. Similar to the `compare()` method, but the result gives a total ordering on `Decimal` instances. Two `Decimal` instances with the same numeric value but different representations compare unequal in this ordering:

```
>>> Decimal('12.0').compare_total(Decimal('12'))
Decimal('-1')
```

Quiet and signaling NaNs are also included in the total ordering. The result of this function is `Decimal('0')` if both operands have the same representation, `Decimal('-1')` if the first operand is lower in the total order than the second, and `Decimal('1')` if the first operand is higher in the total order than the second operand. See the specification for details of the total order. New in version 2.6.

**compare\_total\_mag(*other*)**

Compare two operands using their abstract representation rather than their value as in `compare_total()`, but ignoring the sign of each operand. `x.compare_total_mag(y)` is equivalent to `x.copy_abs().compare_total(y.copy_abs())`. New in version 2.6.

**conjugate()**

Just returns self, this method is only to comply with the Decimal Specification. New in version 2.6.

**copy\_abs()**

Return the absolute value of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed. New in version 2.6.

**copy\_negate()**

Return the negation of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed. New in version 2.6.

**copy\_sign** (*other*)

Return a copy of the first operand with the sign set to be the same as the sign of the second operand. For example:

```
>>> Decimal('2.3').copy_sign(Decimal('-1.5'))
Decimal('-2.3')
```

This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed. New in version 2.6.

**exp** ([*context*])

Return the value of the (natural) exponential function  $e^{**x}$  at the given number. The result is correctly rounded using the ROUND\_HALF\_EVEN rounding mode.

```
>>> Decimal(1).exp()
Decimal('2.718281828459045235360287471')
>>> Decimal(321).exp()
Decimal('2.561702493119680037517373933E+139')
```

New in version 2.6.

**from\_float** (*f*)

Classmethod that converts a float to a decimal number, exactly.

Note `Decimal.from_float(0.1)` is not the same as `Decimal('0.1')`. Since 0.1 is not exactly representable in binary floating point, the value is stored as the nearest representable value which is  $0x1.999999999999ap-4$ . That equivalent value in decimal is `0.1000000000000000055511151231257827021181583404541015625`.

---

**Note:** From Python 2.7 onwards, a `Decimal` instance can also be constructed directly from a `float`.

---

```
>>> Decimal.from_float(0.1)
Decimal('0.1000000000000000055511151231257827021181583404541015625')
>>> Decimal.from_float(float('nan'))
Decimal('NaN')
>>> Decimal.from_float(float('inf'))
Decimal('Infinity')
>>> Decimal.from_float(float('-inf'))
Decimal('-Infinity')
```

New in version 2.7.

**fma** (*other*, *third*[, *context*])

Fused multiply-add. Return `self*other+third` with no rounding of the intermediate product `self*other`.

```
>>> Decimal(2).fma(3, 5)
Decimal('11')
```

New in version 2.6.

**is\_canonical** ()

Return `True` if the argument is canonical and `False` otherwise. Currently, a `Decimal` instance is always canonical, so this operation always returns `True`. New in version 2.6.

**is\_finite()**

Return `True` if the argument is a finite number, and `False` if the argument is an infinity or a NaN. New in version 2.6.

**is\_infinite()**

Return `True` if the argument is either positive or negative infinity and `False` otherwise. New in version 2.6.

**is\_nan()**

Return `True` if the argument is a (quiet or signaling) NaN and `False` otherwise. New in version 2.6.

**is\_normal()**

Return `True` if the argument is a *normal* finite non-zero number with an adjusted exponent greater than or equal to *Emin*. Return `False` if the argument is zero, subnormal, infinite or a NaN. Note, the term *normal* is used here in a different sense with the `normalize()` method which is used to create canonical values. New in version 2.6.

**is\_qnan()**

Return `True` if the argument is a quiet NaN, and `False` otherwise. New in version 2.6.

**is\_signed()**

Return `True` if the argument has a negative sign and `False` otherwise. Note that zeros and NaNs can both carry signs. New in version 2.6.

**is\_snan()**

Return `True` if the argument is a signaling NaN and `False` otherwise. New in version 2.6.

**is\_subnormal()**

Return `True` if the argument is subnormal, and `False` otherwise. A number is subnormal if it is nonzero, finite, and has an adjusted exponent less than *Emin*. New in version 2.6.

**is\_zero()**

Return `True` if the argument is a (positive or negative) zero and `False` otherwise. New in version 2.6.

**ln([context])**

Return the natural (base e) logarithm of the operand. The result is correctly rounded using the `ROUND_HALF_EVEN` rounding mode. New in version 2.6.

**log10([context])**

Return the base ten logarithm of the operand. The result is correctly rounded using the `ROUND_HALF_EVEN` rounding mode. New in version 2.6.

**logb([context])**

For a nonzero number, return the adjusted exponent of its operand as a `Decimal` instance. If the operand is a zero then `Decimal('-Infinity')` is returned and the `DivisionByZero` flag is raised. If the operand is an infinity then `Decimal('Infinity')` is returned. New in version 2.6.

**logical\_and(other[, context])**

`logical_and()` is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise and of the two operands. New in version 2.6.

**logical\_invert([context])**

`logical_invert()` is a logical operation. The result is the digit-wise inversion of the operand. New in version 2.6.

**logical\_or(other[, context])**

`logical_or()` is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise or of the two operands. New in version 2.6.

**logical\_xor(other[, context])**

`logical_xor()` is a logical operation which takes two *logical operands* (see *Logical operands*). The

result is the digit-wise exclusive or of the two operands. New in version 2.6.

**max** (*other* [, *context* ])

Like `max(self, other)` except that the context rounding rule is applied before returning and that NaN values are either signaled or ignored (depending on the context and whether they are signaling or quiet).

**max\_mag** (*other* [, *context* ])

Similar to the `max()` method, but the comparison is done using the absolute values of the operands. New in version 2.6.

**min** (*other* [, *context* ])

Like `min(self, other)` except that the context rounding rule is applied before returning and that NaN values are either signaled or ignored (depending on the context and whether they are signaling or quiet).

**min\_mag** (*other* [, *context* ])

Similar to the `min()` method, but the comparison is done using the absolute values of the operands. New in version 2.6.

**next\_minus** ([*context* ])

Return the largest number representable in the given context (or in the current thread's context if no context is given) that is smaller than the given operand. New in version 2.6.

**next\_plus** ([*context* ])

Return the smallest number representable in the given context (or in the current thread's context if no context is given) that is larger than the given operand. New in version 2.6.

**next\_toward** (*other* [, *context* ])

If the two operands are unequal, return the number closest to the first operand in the direction of the second operand. If both operands are numerically equal, return a copy of the first operand with the sign set to be the same as the sign of the second operand. New in version 2.6.

**normalize** ([*context* ])

Normalize the number by stripping the rightmost trailing zeros and converting any result equal to `Decimal('0')` to `Decimal('0e0')`. Used for producing canonical values for attributes of an equivalence class. For example, `Decimal('32.100')` and `Decimal('0.321000e+2')` both normalize to the equivalent value `Decimal('32.1')`.

**number\_class** ([*context* ])

Return a string describing the *class* of the operand. The returned value is one of the following ten strings.

- "-Infinity", indicating that the operand is negative infinity.
- "-Normal", indicating that the operand is a negative normal number.
- "-Subnormal", indicating that the operand is negative and subnormal.
- "-Zero", indicating that the operand is a negative zero.
- "+Zero", indicating that the operand is a positive zero.
- "+Subnormal", indicating that the operand is positive and subnormal.
- "+Normal", indicating that the operand is a positive normal number.
- "+Infinity", indicating that the operand is positive infinity.
- "NaN", indicating that the operand is a quiet NaN (Not a Number).
- "sNaN", indicating that the operand is a signaling NaN.

New in version 2.6.

**quantize** (*exp* [, *rounding* [, *context* [, *watchexp* ] ] ])

Return a value equal to the first operand after rounding and having the exponent of the second operand.

```
>>> Decimal('1.41421356').quantize(Decimal('1.000'))
Decimal('1.414')
```

Unlike other operations, if the length of the coefficient after the quantize operation would be greater than precision, then an `InvalidOperation` is signaled. This guarantees that, unless there is an error condition, the quantized exponent is always equal to that of the right-hand operand.

Also unlike other operations, quantize never signals Underflow, even if the result is subnormal and inexact.

If the exponent of the second operand is larger than that of the first then rounding may be necessary. In this case, the rounding mode is determined by the `rounding` argument if given, else by the given `context` argument; if neither argument is given the rounding mode of the current thread's context is used.

If `watchexp` is set (default), then an error is returned whenever the resulting exponent is greater than `Emax` or less than `Etiny`.

**radix()**

Return `Decimal(10)`, the radix (base) in which the `Decimal` class does all its arithmetic. Included for compatibility with the specification. New in version 2.6.

**remainder\_near(*other*[, *context*])**

Compute the modulo as either a positive or negative value depending on which is closest to zero. For instance, `Decimal(10).remainder_near(6)` returns `Decimal('-2')` which is closer to zero than `Decimal('4')`.

If both are equally close, the one chosen will have the same sign as *self*.

**rotate(*other*[, *context*])**

Return the result of rotating the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range `-precision` through `precision`. The absolute value of the second operand gives the number of places to rotate. If the second operand is positive then rotation is to the left; otherwise rotation is to the right. The coefficient of the first operand is padded on the left with zeros to length `precision` if necessary. The sign and exponent of the first operand are unchanged. New in version 2.6.

**same\_quantum(*other*[, *context*])**

Test whether *self* and *other* have the same exponent or whether both are NaN.

**scaleb(*other*[, *context*])**

Return the first operand with exponent adjusted by the second. Equivalently, return the first operand multiplied by `10**other`. The second operand must be an integer. New in version 2.6.

**shift(*other*[, *context*])**

Return the result of shifting the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range `-precision` through `precision`. The absolute value of the second operand gives the number of places to shift. If the second operand is positive then the shift is to the left; otherwise the shift is to the right. Digits shifted into the coefficient are zeros. The sign and exponent of the first operand are unchanged. New in version 2.6.

**sqrt([*context*])**

Return the square root of the argument to full precision.

**to\_eng\_string([*context*])**

Convert to an engineering-type string.

Engineering notation has an exponent which is a multiple of 3, so there are up to 3 digits left of the decimal place. For example, converts `Decimal('123E+1')` to `Decimal('1.23E+3')`

**to\_integral([*rounding*[, *context*]])**

Identical to the `to_integral_value()` method. The `to_integral` name has been kept for compatibility with older versions.

`to_integral_exact` (*[rounding[, context]]*)

Round to the nearest integer, signaling `Inexact` or `Rounded` as appropriate if rounding occurs. The rounding mode is determined by the `rounding` parameter if given, else by the given `context`. If neither parameter is given then the rounding mode of the current context is used. New in version 2.6.

`to_integral_value` (*[rounding[, context]]*)

Round to the nearest integer without signaling `Inexact` or `Rounded`. If given, applies *rounding*; otherwise, uses the rounding method in either the supplied *context* or the current context. Changed in version 2.6: renamed from `to_integral` to `to_integral_value`. The old name remains valid for compatibility.

## Logical operands

The `logical_and()`, `logical_invert()`, `logical_or()`, and `logical_xor()` methods expect their arguments to be *logical operands*. A *logical operand* is a `Decimal` instance whose exponent and sign are both zero, and whose digits are all either 0 or 1.

### 9.4.3 Context objects

Contexts are environments for arithmetic operations. They govern precision, set rules for rounding, determine which signals are treated as exceptions, and limit the range for exponents.

Each thread has its own current context which is accessed or changed using the `getcontext()` and `setcontext()` functions:

`decimal.getcontext()`

Return the current context for the active thread.

`decimal.setcontext(c)`

Set the current context for the active thread to *c*.

Beginning with Python 2.5, you can also use the `with` statement and the `localcontext()` function to temporarily change the active context.

`decimal.localcontext([c])`

Return a context manager that will set the current context for the active thread to a copy of *c* on entry to the `with`-statement and restore the previous context when exiting the `with`-statement. If no context is specified, a copy of the current context is used. New in version 2.5. For example, the following code sets the current decimal precision to 42 places, performs a calculation, and then automatically restores the previous context:

```
from decimal import localcontext

with localcontext() as ctx:
    ctx.prec = 42    # Perform a high precision calculation
    s = calculate_something()
s = +s    # Round the final result back to the default precision

with localcontext(BasicContext):    # temporarily use the BasicContext
    print Decimal(1) / Decimal(7)
    print Decimal(355) / Decimal(113)
```

New contexts can also be created using the `Context` constructor described below. In addition, the module provides three pre-made contexts:

**class** `decimal.BasicContext`

This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine.

Rounding is set to `ROUND_HALF_UP`. All flags are cleared. All traps are enabled (treated as exceptions) except `Inexact`, `Rounded`, and `Subnormal`.

Because many of the traps are enabled, this context is useful for debugging.

### **class** `decimal.ExtendedContext`

This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine. Rounding is set to `ROUND_HALF_EVEN`. All flags are cleared. No traps are enabled (so that exceptions are not raised during computations).

Because the traps are disabled, this context is useful for applications that prefer to have result value of `NaN` or `Infinity` instead of raising exceptions. This allows an application to complete a run in the presence of conditions that would otherwise halt the program.

### **class** `decimal.DefaultContext`

This context is used by the `Context` constructor as a prototype for new contexts. Changing a field (such as precision) has the effect of changing the default for new contexts created by the `Context` constructor.

This context is most useful in multi-threaded environments. Changing one of the fields before threads are started has the effect of setting system-wide defaults. Changing the fields after threads have started is not recommended as it would require thread synchronization to prevent race conditions.

In single threaded environments, it is preferable to not use this context at all. Instead, simply create contexts explicitly as described below.

The default values are `precision=28`, `rounding=ROUND_HALF_EVEN`, and enabled traps for `Overflow`, `InvalidOperation`, and `DivisionByZero`.

In addition to the three supplied contexts, new contexts can be created with the `Context` constructor.

### **class** `decimal.Context` (*prec=None, rounding=None, traps=None, flags=None, Emin=None, Emax=None, capitals=1*)

Creates a new context. If a field is not specified or is `None`, the default values are copied from the `DefaultContext`. If the `flags` field is not specified or is `None`, all flags are cleared.

The `prec` field is a positive integer that sets the precision for arithmetic operations in the context.

The `rounding` option is one of:

- `ROUND_CEILING` (towards `Infinity`),
- `ROUND_DOWN` (towards zero),
- `ROUND_FLOOR` (towards `-Infinity`),
- `ROUND_HALF_DOWN` (to nearest with ties going towards zero),
- `ROUND_HALF_EVEN` (to nearest with ties going to nearest even integer),
- `ROUND_HALF_UP` (to nearest with ties going away from zero), or
- `ROUND_UP` (away from zero).
- `ROUND_05UP` (away from zero if last digit after rounding towards zero would have been 0 or 5; otherwise towards zero)

The `traps` and `flags` fields list any signals to be set. Generally, new contexts should only set traps and leave the flags clear.

The `Emin` and `Emax` fields are integers specifying the outer limits allowable for exponents.

The `capitals` field is either 0 or 1 (the default). If set to 1, exponents are printed with a capital E; otherwise, a lowercase e is used: `Decimal('6.02e+23')`. Changed in version 2.6: The `ROUND_05UP` rounding mode was added. The `Context` class defines several general purpose methods as well as a large number of methods for doing arithmetic directly in a given context. In addition, for each of the `Decimal` methods

described above (with the exception of the `adjusted()` and `as_tuple()` methods) there is a corresponding `Context` method. For example, for a `Context` instance `C` and `Decimal` instance `x`, `C.exp(x)` is equivalent to `x.exp(context=C)`. Each `Context` method accepts a Python integer (an instance of `int` or `long`) anywhere that a `Decimal` instance is accepted.

**`clear_flags()`**

Resets all of the flags to 0.

**`copy()`**

Return a duplicate of the context.

**`copy_decimal(num)`**

Return a copy of the `Decimal` instance `num`.

**`create_decimal(num)`**

Creates a new `Decimal` instance from `num` but using `self` as context. Unlike the `Decimal` constructor, the context precision, rounding method, flags, and traps are applied to the conversion.

This is useful because constants are often given to a greater precision than is needed by the application. Another benefit is that rounding immediately eliminates unintended effects from digits beyond the current precision. In the following example, using unrounded inputs means that adding zero to a sum can change the result:

```
>>> getcontext().prec = 3
>>> Decimal('3.4445') + Decimal('1.0023')
Decimal('4.45')
>>> Decimal('3.4445') + Decimal(0) + Decimal('1.0023')
Decimal('4.44')
```

This method implements the to-number operation of the IBM specification. If the argument is a string, no leading or trailing whitespace is permitted.

**`create_decimal_from_float(f)`**

Creates a new `Decimal` instance from a float `f` but rounding using `self` as the context. Unlike the `Decimal.from_float()` class method, the context precision, rounding method, flags, and traps are applied to the conversion.

```
>>> context = Context(prec=5, rounding=ROUND_DOWN)
>>> context.create_decimal_from_float(math.pi)
Decimal('3.1415')
>>> context = Context(prec=5, traps=[Inexact])
>>> context.create_decimal_from_float(math.pi)
Traceback (most recent call last):
...
Inexact: None
```

New in version 2.7.

**`Etiny()`**

Returns a value equal to  $E_{min} - prec + 1$  which is the minimum exponent value for subnormal results. When underflow occurs, the exponent is set to `Etiny`.

**`Etop()`**

Returns a value equal to  $E_{max} - prec + 1$ .

The usual approach to working with decimals is to create `Decimal` instances and then apply arithmetic operations which take place within the current context for the active thread. An alternative approach is to use context

methods for calculating within a specific context. The methods are similar to those for the `Decimal` class and are only briefly recounted here.

**abs** (*x*)

Returns the absolute value of *x*.

**add** (*x*, *y*)

Return the sum of *x* and *y*.

**canonical** (*x*)

Returns the same `Decimal` object *x*.

**compare** (*x*, *y*)

Compares *x* and *y* numerically.

**compare\_signal** (*x*, *y*)

Compares the values of the two operands numerically.

**compare\_total** (*x*, *y*)

Compares two operands using their abstract representation.

**compare\_total\_mag** (*x*, *y*)

Compares two operands using their abstract representation, ignoring sign.

**copy\_abs** (*x*)

Returns a copy of *x* with the sign set to 0.

**copy\_negate** (*x*)

Returns a copy of *x* with the sign inverted.

**copy\_sign** (*x*, *y*)

Copies the sign from *y* to *x*.

**divide** (*x*, *y*)

Return *x* divided by *y*.

**divide\_int** (*x*, *y*)

Return *x* divided by *y*, truncated to an integer.

**divmod** (*x*, *y*)

Divides two numbers and returns the integer part of the result.

**exp** (*x*)

Returns  $e^{**}x$ .

**fma** (*x*, *y*, *z*)

Returns *x* multiplied by *y*, plus *z*.

**is\_canonical** (*x*)

Returns True if *x* is canonical; otherwise returns False.

**is\_finite** (*x*)

Returns True if *x* is finite; otherwise returns False.

**is\_infinite** (*x*)

Returns True if *x* is infinite; otherwise returns False.

**is\_nan** (*x*)

Returns True if *x* is a qNaN or sNaN; otherwise returns False.

**is\_normal** (*x*)

Returns True if *x* is a normal number; otherwise returns False.

**is\_qnan** (*x*)  
Returns True if *x* is a quiet NaN; otherwise returns False.

**is\_signed** (*x*)  
Returns True if *x* is negative; otherwise returns False.

**is\_snan** (*x*)  
Returns True if *x* is a signaling NaN; otherwise returns False.

**is\_subnormal** (*x*)  
Returns True if *x* is subnormal; otherwise returns False.

**is\_zero** (*x*)  
Returns True if *x* is a zero; otherwise returns False.

**ln** (*x*)  
Returns the natural (base e) logarithm of *x*.

**log10** (*x*)  
Returns the base 10 logarithm of *x*.

**logb** (*x*)  
Returns the exponent of the magnitude of the operand's MSD.

**logical\_and** (*x*, *y*)  
Applies the logical operation *and* between each operand's digits.

**logical\_invert** (*x*)  
Invert all the digits in *x*.

**logical\_or** (*x*, *y*)  
Applies the logical operation *or* between each operand's digits.

**logical\_xor** (*x*, *y*)  
Applies the logical operation *xor* between each operand's digits.

**max** (*x*, *y*)  
Compares two values numerically and returns the maximum.

**max\_mag** (*x*, *y*)  
Compares the values numerically with their sign ignored.

**min** (*x*, *y*)  
Compares two values numerically and returns the minimum.

**min\_mag** (*x*, *y*)  
Compares the values numerically with their sign ignored.

**minus** (*x*)  
Minus corresponds to the unary prefix minus operator in Python.

**multiply** (*x*, *y*)  
Return the product of *x* and *y*.

**next\_minus** (*x*)  
Returns the largest representable number smaller than *x*.

**next\_plus** (*x*)  
Returns the smallest representable number larger than *x*.

**next\_toward** (*x*, *y*)  
Returns the number closest to *x*, in direction towards *y*.

**normalize** (*x*)

Reduces *x* to its simplest form.

**number\_class** (*x*)

Returns an indication of the class of *x*.

**plus** (*x*)

Plus corresponds to the unary prefix plus operator in Python. This operation applies the context precision and rounding, so it is *not* an identity operation.

**power** (*x*, *y*[, *modulo* ])

Return *x* to the power of *y*, reduced modulo *modulo* if given.

With two arguments, compute  $x^{**}y$ . If *x* is negative then *y* must be integral. The result will be inexact unless *y* is integral and the result is finite and can be expressed exactly in ‘precision’ digits. The result should always be correctly rounded, using the rounding mode of the current thread’s context.

With three arguments, compute  $(x^{**}y) \% modulo$ . For the three argument form, the following restrictions on the arguments hold:

- all three arguments must be integral
- y* must be nonnegative
- at least one of *x* or *y* must be nonzero
- modulo* must be nonzero and have at most ‘precision’ digits

The value resulting from `Context.power(x, y, modulo)` is equal to the value that would be obtained by computing  $(x^{**}y) \% modulo$  with unbounded precision, but is computed more efficiently. The exponent of the result is zero, regardless of the exponents of *x*, *y* and *modulo*. The result is always exact. Changed in version 2.6: *y* may now be nonintegral in  $x^{**}y$ . Stricter requirements for the three-argument version.

**quantize** (*x*, *y*)

Returns a value equal to *x* (rounded), having the exponent of *y*.

**radix** ()

Just returns 10, as this is Decimal, :)

**remainder** (*x*, *y*)

Returns the remainder from integer division.

The sign of the result, if non-zero, is the same as that of the original dividend.

**remainder\_near** (*x*, *y*)

Returns  $x - y * n$ , where *n* is the integer nearest the exact value of  $x / y$  (if the result is 0 then its sign will be the sign of *x*).

**rotate** (*x*, *y*)

Returns a rotated copy of *x*, *y* times.

**same\_quantum** (*x*, *y*)

Returns True if the two operands have the same exponent.

**scaleb** (*x*, *y*)

Returns the first operand after adding the second value its exp.

**shift** (*x*, *y*)

Returns a shifted copy of *x*, *y* times.

**sqrt** (*x*)

Square root of a non-negative number to context precision.

**subtract** (*x*, *y*)  
Return the difference between *x* and *y*.

**to\_eng\_string** (*x*)  
Converts a number to a string, using scientific notation.

**to\_integral\_exact** (*x*)  
Rounds to an integer.

**to\_sci\_string** (*x*)  
Converts a number to a string using scientific notation.

## 9.4.4 Signals

Signals represent conditions that arise during computation. Each corresponds to one context flag and one context trap enabler.

The context flag is set whenever the condition is encountered. After the computation, flags may be checked for informational purposes (for instance, to determine whether a computation was exact). After checking the flags, be sure to clear all flags before starting the next computation.

If the context's trap enabler is set for the signal, then the condition causes a Python exception to be raised. For example, if the `DivisionByZero` trap is set, then a `DivisionByZero` exception is raised upon encountering the condition.

**class** `decimal.Clamped`  
Altered an exponent to fit representation constraints.

Typically, clamping occurs when an exponent falls outside the context's `Emin` and `Emax` limits. If possible, the exponent is reduced to fit by adding zeros to the coefficient.

**class** `decimal.DecimalException`  
Base class for other signals and a subclass of `ArithmeticError`.

**class** `decimal.DivisionByZero`  
Signals the division of a non-infinite number by zero.

Can occur with division, modulo division, or when raising a number to a negative power. If this signal is not trapped, returns `Infinity` or `-Infinity` with the sign determined by the inputs to the calculation.

**class** `decimal.Inexact`  
Indicates that rounding occurred and the result is not exact.

Signals when non-zero digits were discarded during rounding. The rounded result is returned. The signal flag or trap is used to detect when results are inexact.

**class** `decimal.InvalidOperation`  
An invalid operation was performed.

Indicates that an operation was requested that does not make sense. If not trapped, returns `NaN`. Possible causes include:

```
Infinity - Infinity
0 * Infinity
Infinity / Infinity
x % 0
Infinity % x
x._rescale( non-integer )
sqrt(-x) and x > 0
0 ** 0
```

```
x ** (non-integer)
x ** Infinity
```

**class** `decimal.Overflow`  
Numerical overflow.

Indicates the exponent is larger than `Emax` after rounding has occurred. If not trapped, the result depends on the rounding mode, either pulling inward to the largest representable finite number or rounding outward to `Infinity`. In either case, `Inexact` and `Rounded` are also signaled.

**class** `decimal.Rounded`  
Rounding occurred though possibly no information was lost.

Signaled whenever rounding discards digits; even if those digits are zero (such as rounding 5.00 to 5.0). If not trapped, returns the result unchanged. This signal is used to detect loss of significant digits.

**class** `decimal.Subnormal`  
Exponent was lower than `Emin` prior to rounding.

Occurs when an operation result is subnormal (the exponent is too small). If not trapped, returns the result unchanged.

**class** `decimal.Underflow`  
Numerical underflow with result rounded to zero.

Occurs when a subnormal result is pushed to zero by rounding. `Inexact` and `Subnormal` are also signaled.

The following table summarizes the hierarchy of signals:

```
exceptions.ArithmeticError(exceptions.StandardError)
  DecimalException
    Clamped
    DivisionByZero(DecimalException, exceptions.ZeroDivisionError)
    Inexact
      Overflow(Inexact, Rounded)
      Underflow(Inexact, Rounded, Subnormal)
    InvalidOperation
    Rounded
    Subnormal
```

## 9.4.5 Floating Point Notes

### Mitigating round-off error with increased precision

The use of decimal floating point eliminates decimal representation error (making it possible to represent 0.1 exactly); however, some operations can still incur round-off error when non-zero digits exceed the fixed precision.

The effects of round-off error can be amplified by the addition or subtraction of nearly offsetting quantities resulting in loss of significance. Knuth provides two instructive examples where rounded floating point arithmetic with insufficient precision causes the breakdown of the associative and distributive properties of addition:

```
# Examples from Seminumerical Algorithms, Section 4.2.2.
>>> from decimal import Decimal, getcontext
>>> getcontext().prec = 8

>>> u, v, w = Decimal(11111113), Decimal(-11111111), Decimal('7.51111111')
>>> (u + v) + w
Decimal('9.5111111')
```

```
>>> u + (v + w)
Decimal('10')

>>> u, v, w = Decimal(20000), Decimal(-6), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.01')
>>> u * (v+w)
Decimal('0.0060000')
```

The `decimal` module makes it possible to restore the identities by expanding the precision sufficiently to avoid loss of significance:

```
>>> getcontext().prec = 20
>>> u, v, w = Decimal(11111113), Decimal(-11111111), Decimal('7.51111111')
>>> (u + v) + w
Decimal('9.51111111')
>>> u + (v + w)
Decimal('9.51111111')
>>>
>>> u, v, w = Decimal(20000), Decimal(-6), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.0060000')
>>> u * (v+w)
Decimal('0.0060000')
```

## Special values

The number system for the `decimal` module provides special values including NaN, sNaN, `-Infinity`, `Infinity`, and two zeros, `+0` and `-0`.

Infinities can be constructed directly with: `Decimal('Infinity')`. Also, they can arise from dividing by zero when the `DivisionByZero` signal is not trapped. Likewise, when the `Overflow` signal is not trapped, infinity can result from rounding beyond the limits of the largest representable number.

The infinities are signed (affine) and can be used in arithmetic operations where they get treated as very large, indeterminate numbers. For instance, adding a constant to infinity gives another infinite result.

Some operations are indeterminate and return NaN, or if the `InvalidOperation` signal is trapped, raise an exception. For example, `0/0` returns NaN which means “not a number”. This variety of NaN is quiet and, once created, will flow through other computations always resulting in another NaN. This behavior can be useful for a series of computations that occasionally have missing inputs — it allows the calculation to proceed while flagging specific results as invalid.

A variant is sNaN which signals rather than remaining quiet after every operation. This is a useful return value when an invalid result needs to interrupt a calculation for special handling.

The behavior of Python’s comparison operators can be a little surprising where a NaN is involved. A test for equality where one of the operands is a quiet or signaling NaN always returns `False` (even when doing `Decimal('NaN')==Decimal('NaN')`), while a test for inequality always returns `True`. An attempt to compare two Decimals using any of the `<`, `<=`, `>` or `>=` operators will raise the `InvalidOperation` signal if either operand is a NaN, and return `False` if this signal is not trapped. Note that the General Decimal Arithmetic specification does not specify the behavior of direct comparisons; these rules for comparisons involving a NaN were taken from the IEEE 854 standard (see Table 3 in section 5.7). To ensure strict standards-compliance, use the `compare()` and `compare-signal()` methods instead.

The signed zeros can result from calculations that underflow. They keep the sign that would have resulted if the calculation had been carried out to greater precision. Since their magnitude is zero, both positive and negative zeros

are treated as equal and their sign is informational.

In addition to the two signed zeros which are distinct yet equal, there are various representations of zero with differing precisions yet equivalent in value. This takes a bit of getting used to. For an eye accustomed to normalized floating point representations, it is not immediately obvious that the following calculation returns a value equal to zero:

```
>>> 1 / Decimal('Infinity')
Decimal('0E-10000000026')
```

### 9.4.6 Working with threads

The `getcontext()` function accesses a different `Context` object for each thread. Having separate thread contexts means that threads may make changes (such as `getcontext().prec=10`) without interfering with other threads.

Likewise, the `setcontext()` function automatically assigns its target to the current thread.

If `setcontext()` has not been called before `getcontext()`, then `getcontext()` will automatically create a new context for use in the current thread.

The new context is copied from a prototype context called `DefaultContext`. To control the defaults so that each thread will use the same values throughout the application, directly modify the `DefaultContext` object. This should be done *before* any threads are started so that there won't be a race condition between threads calling `getcontext()`. For example:

```
# Set applicationwide defaults for all threads about to be launched
DefaultContext.prec = 12
DefaultContext.rounding = ROUND_DOWN
DefaultContext.traps = ExtendedContext.traps.copy()
DefaultContext.traps[InvalidOperation] = 1
setcontext(DefaultContext)

# Afterwards, the threads can be started
t1.start()
t2.start()
t3.start()
. . .
```

### 9.4.7 Recipes

Here are a few recipes that serve as utility functions and that demonstrate ways to work with the `Decimal` class:

```
def moneyfmt(value, places=2, curr='', sep=',', dp='.',
             pos='', neg='-', trailneg=''):
    """Convert Decimal to a money formatted string.

    places:  required number of places after the decimal point
    curr:    optional currency symbol before the sign (may be blank)
    sep:     optional grouping separator (comma, period, space, or blank)
    dp:      decimal point indicator (comma or period)
             only specify as blank when places is zero
    pos:     optional sign for positive numbers: '+', space or blank
    neg:     optional sign for negative numbers: '-', '(', space or blank
    trailneg: optional trailing minus indicator: '-', ')', space or blank

    >>> d = Decimal('-1234567.8901')
    >>> moneyfmt(d, curr='$')
```

```

'-$1,234,567.89'
>>> moneyfmt(d, places=0, sep='.', dp='', neg='', trailneg='-')
'1.234.568-'
>>> moneyfmt(d, curr='$', neg='(', trailneg='')
'($1,234,567.89)'
>>> moneyfmt(Decimal(123456789), sep=' ')
'123 456 789.00'
>>> moneyfmt(Decimal('-0.02'), neg='<', trailneg='>')
'<0.02>'

"""
q = Decimal(10) ** -places          # 2 places --> '0.01'
sign, digits, exp = value.quantize(q).as_tuple()
result = []
digits = map(str, digits)
build, next = result.append, digits.pop
if sign:
    build(trailneg)
for i in range(places):
    build(next() if digits else '0')
build(dp)
if not digits:
    build('0')
i = 0
while digits:
    build(next())
    i += 1
    if i == 3 and digits:
        i = 0
        build(sep)
build(curr)
build(neg if sign else pos)
return ''.join(reversed(result))

def pi():
    """Compute Pi to the current precision.

    >>> print pi()
    3.141592653589793238462643383

    """
    getcontext().prec += 2 # extra digits for intermediate steps
    three = Decimal(3)    # substitute "three=3.0" for regular floats
    lasts, t, s, n, na, d, da = 0, three, 3, 1, 0, 0, 24
    while s != lasts:
        lasts = s
        n, na = n+na, na+8
        d, da = d+da, da+32
        t = (t * n) / d
        s += t
    getcontext().prec -= 2
    return +s                # unary plus applies the new precision

def exp(x):

```

```
"""Return e raised to the power of x. Result type matches input type.
```

```
>>> print exp(Decimal(1))
2.718281828459045235360287471
>>> print exp(Decimal(2))
7.389056098930650227230427461
>>> print exp(2.0)
7.38905609893
>>> print exp(2+0j)
(7.38905609893+0j)
```

```
"""
getcontext().prec += 2
i, lasts, s, fact, num = 0, 0, 1, 1, 1
while s != lasts:
    lasts = s
    i += 1
    fact *= i
    num *= x
    s += num / fact
getcontext().prec -= 2
return +s
```

```
def cos(x):
    """Return the cosine of x as measured in radians.
```

```
>>> print cos(Decimal('0.5'))
0.8775825618903727161162815826
>>> print cos(0.5)
0.87758256189
>>> print cos(0.5+0j)
(0.87758256189+0j)
```

```
"""
getcontext().prec += 2
i, lasts, s, fact, num, sign = 0, 0, 1, 1, 1, 1
while s != lasts:
    lasts = s
    i += 2
    fact *= i * (i-1)
    num *= x * x
    sign *= -1
    s += num / fact * sign
getcontext().prec -= 2
return +s
```

```
def sin(x):
    """Return the sine of x as measured in radians.
```

```
>>> print sin(Decimal('0.5'))
0.4794255386042030002732879352
>>> print sin(0.5)
0.479425538604
>>> print sin(0.5+0j)
```

```
(0.479425538604+0j)

"""
getcontext().prec += 2
i, lasts, s, fact, num, sign = 1, 0, x, 1, x, 1
while s != lasts:
    lasts = s
    i += 2
    fact *= i * (i-1)
    num *= x * x
    sign *= -1
    s += num / fact * sign
getcontext().prec -= 2
return +s
```

### 9.4.8 Decimal FAQ

Q. It is cumbersome to type `decimal.Decimal('1234.5')`. Is there a way to minimize typing when using the interactive interpreter?

A. Some users abbreviate the constructor to just a single letter:

```
>>> D = decimal.Decimal
>>> D('1.23') + D('3.45')
Decimal('4.68')
```

Q. In a fixed-point application with two decimal places, some inputs have many places and need to be rounded. Others are not supposed to have excess digits and need to be validated. What methods should be used?

A. The `quantize()` method rounds to a fixed number of decimal places. If the `Inexact` trap is set, it is also useful for validation:

```
>>> TWOPLACES = Decimal(10) ** -2          # same as Decimal('0.01')
>>> # Round to two places
>>> Decimal('3.214').quantize(TWOPLACES)
Decimal('3.21')
>>> # Validate that a number does not exceed two places
>>> Decimal('3.21').quantize(TWOPLACES, context=Context(traps=[Inexact]))
Decimal('3.21')
>>> Decimal('3.214').quantize(TWOPLACES, context=Context(traps=[Inexact]))
Traceback (most recent call last):
...
Inexact: None
```

Q. Once I have valid two place inputs, how do I maintain that invariant throughout an application?

A. Some operations like addition, subtraction, and multiplication by an integer will automatically preserve fixed point. Others operations, like division and non-integer multiplication, will change the number of decimal places and need to be followed-up with a `quantize()` step:

```
>>> a = Decimal('102.72')                # Initial fixed-point values
>>> b = Decimal('3.17')
>>> a + b                                # Addition preserves fixed-point
Decimal('105.89')
>>> a - b
Decimal('99.55')
```

```
>>> a * 42                                     # So does integer multiplication
Decimal('4314.24')
>>> (a * b).quantize(TWOPLACES)               # Must quantize non-integer multiplication
Decimal('325.62')
>>> (b / a).quantize(TWOPLACES)               # And quantize division
Decimal('0.03')
```

In developing fixed-point applications, it is convenient to define functions to handle the `quantize()` step:

```
>>> def mul(x, y, fp=TWOPLACES):
...     return (x * y).quantize(fp)
>>> def div(x, y, fp=TWOPLACES):
...     return (x / y).quantize(fp)

>>> mul(a, b)                                   # Automatically preserve fixed-point
Decimal('325.62')
>>> div(b, a)
Decimal('0.03')
```

Q. There are many ways to express the same value. The numbers 200, 200.000, 2E2, and 02E+4 all have the same value at various precisions. Is there a way to transform them to a single recognizable canonical value?

A. The `normalize()` method maps all equivalent values to a single representative:

```
>>> values = map(Decimal, '200 200.000 2E2 .02E+4'.split())
>>> [v.normalize() for v in values]
[Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2')]
```

Q. Some decimal values always print with exponential notation. Is there a way to get a non-exponential representation?

A. For some values, exponential notation is the only way to express the number of significant places in the coefficient. For example, expressing 5.0E+3 as 5000 keeps the value constant but cannot show the original's two-place significance.

If an application does not care about tracking significance, it is easy to remove the exponent and trailing zeros, losing significance, but keeping the value unchanged:

```
def remove_exponent(d):
    '''Remove exponent and trailing zeros.

    >>> remove_exponent(Decimal('5E+3'))
    Decimal('5000')

    '''
    return d.quantize(Decimal(1)) if d == d.to_integral() else d.normalize()
```

Q. Is there a way to convert a regular float to a `Decimal`?

A. Yes, any binary floating point number can be exactly expressed as a `Decimal` though an exact conversion may take more precision than intuition would suggest:

```
>>> Decimal(math.pi)
Decimal('3.141592653589793115997963468544185161590576171875')
```

Q. Within a complex calculation, how can I make sure that I haven't gotten a spurious result because of insufficient precision or rounding anomalies.

A. The decimal module makes it easy to test results. A best practice is to re-run calculations using greater precision and with various rounding modes. Widely differing results indicate insufficient precision, rounding mode issues, ill-conditioned inputs, or a numerically unstable algorithm.

Q. I noticed that context precision is applied to the results of operations but not to the inputs. Is there anything to watch out for when mixing values of different precisions?

A. Yes. The principle is that all values are considered to be exact and so is the arithmetic on those values. Only the results are rounded. The advantage for inputs is that “what you type is what you get”. A disadvantage is that the results can look odd if you forget that the inputs haven’t been rounded:

```
>>> getcontext().prec = 3
>>> Decimal('3.104') + Decimal('2.104')
Decimal('5.21')
>>> Decimal('3.104') + Decimal('0.000') + Decimal('2.104')
Decimal('5.20')
```

The solution is either to increase precision or to force rounding of inputs using the unary plus operation:

```
>>> getcontext().prec = 3
>>> +Decimal('1.23456789')      # unary plus triggers rounding
Decimal('1.23')
```

Alternatively, inputs can be rounded upon creation using the `Context.create_decimal()` method:

```
>>> Context(prec=5, rounding=ROUND_DOWN).create_decimal('1.2345678')
Decimal('1.2345')
```

## 9.5 fractions — Rational numbers

New in version 2.6. **Source code:** [Lib/fractions.py](#)

The `fractions` module provides support for rational number arithmetic.

A `Fraction` instance can be constructed from a pair of integers, from another rational number, or from a string.

```
class fractions.Fraction (numerator=0, denominator=1)
class fractions.Fraction (other_fraction)
class fractions.Fraction (float)
class fractions.Fraction (decimal)
class fractions.Fraction (string)
```

The first version requires that `numerator` and `denominator` are instances of `numbers.Rational` and returns a new `Fraction` instance with value `numerator/denominator`. If `denominator` is 0, it raises a `ZeroDivisionError`. The second version requires that `other_fraction` is an instance of `numbers.Rational` and returns a `Fraction` instance with the same value. The next two versions accept either a `float` or a `decimal.Decimal` instance, and return a `Fraction` instance with exactly the same value. Note that due to the usual issues with binary floating-point (see *tut-fp-issues*), the argument to `Fraction(1.1)` is not exactly equal to `11/10`, and so `Fraction(1.1)` does *not* return `Fraction(11, 10)` as one might expect. (But see the documentation for the `limit_denominator()` method below.) The last version of the constructor expects a string or unicode instance. The usual form for this instance is:

```
[sign] numerator [ '/' denominator ]
```

where the optional `sign` may be either `+` or `-` and `numerator` and `denominator` (if present) are strings of decimal digits. In addition, any string that represents a finite value and is accepted by the `float` constructor is also accepted by the `Fraction` constructor. In either form the input string may also have leading and/or trailing whitespace. Here are some examples:

```
>>> from fractions import Fraction
>>> Fraction(16, -10)
Fraction(-8, 5)
>>> Fraction(123)
Fraction(123, 1)
>>> Fraction()
Fraction(0, 1)
>>> Fraction('3/7')
Fraction(3, 7)
[40794 refs]
>>> Fraction(' -3/7 ')
Fraction(-3, 7)
>>> Fraction('1.414213 \t\n')
Fraction(1414213, 1000000)
>>> Fraction('-.125')
Fraction(-1, 8)
>>> Fraction('7e-6')
Fraction(7, 1000000)
>>> Fraction(2.25)
Fraction(9, 4)
>>> Fraction(1.1)
Fraction(2476979795053773, 2251799813685248)
>>> from decimal import Decimal
>>> Fraction(Decimal('1.1'))
Fraction(11, 10)
```

The `Fraction` class inherits from the abstract base class `numbers.Rational`, and implements all of the methods and operations from that class. `Fraction` instances are hashable, and should be treated as immutable. In addition, `Fraction` has the following methods: Changed in version 2.7: The `Fraction` constructor now accepts `float` and `decimal.Decimal` instances.

**from\_float** (*flt*)

This class method constructs a `Fraction` representing the exact value of *flt*, which must be a `float`. Beware that `Fraction.from_float(0.3)` is not the same value as `Fraction(3, 10)`

---

**Note:** From Python 2.7 onwards, you can also construct a `Fraction` instance directly from a `float`.

---

**from\_decimal** (*dec*)

This class method constructs a `Fraction` representing the exact value of *dec*, which must be a `decimal.Decimal`.

---

**Note:** From Python 2.7 onwards, you can also construct a `Fraction` instance directly from a `decimal.Decimal` instance.

---

**limit\_denominator** (*max\_denominator=1000000*)

Finds and returns the closest `Fraction` to *self* that has denominator at most *max\_denominator*. This method is useful for finding rational approximations to a given floating-point number:

```
>>> from fractions import Fraction
>>> Fraction('3.1415926535897932').limit_denominator(1000)
Fraction(355, 113)
```

or for recovering a rational number that's represented as a float:

```

>>> from math import pi, cos
>>> Fraction(cos(pi/3))
Fraction(4503599627370497, 9007199254740992)
>>> Fraction(cos(pi/3)).limit_denominator()
Fraction(1, 2)
>>> Fraction(1.1).limit_denominator()
Fraction(11, 10)

```

`fractions.gcd(a, b)`

Return the greatest common divisor of the integers *a* and *b*. If either *a* or *b* is nonzero, then the absolute value of `gcd(a, b)` is the largest integer that divides both *a* and *b*. `gcd(a, b)` has the same sign as *b* if *b* is nonzero; otherwise it takes the sign of *a*. `gcd(0, 0)` returns 0.

**See Also:**

**Module `numbers`** The abstract base classes making up the numeric tower.

## 9.6 random — Generate pseudo-random numbers

**Source code:** [Lib/random.py](#)

This module implements pseudo-random number generators for various distributions.

For integers, uniform selection from a range. For sequences, uniform selection of a random element, a function to generate a random permutation of a list in-place, and a function for random sampling without replacement.

On the real line, there are functions to compute uniform, normal (Gaussian), lognormal, negative exponential, gamma, and beta distributions. For generating distributions of angles, the von Mises distribution is available.

Almost all module functions depend on the basic function `random()`, which generates a random float uniformly in the semi-open range [0.0, 1.0). Python uses the Mersenne Twister as the core generator. It produces 53-bit precision floats and has a period of  $2^{19937}-1$ . The underlying implementation in C is both fast and threadsafe. The Mersenne Twister is one of the most extensively tested random number generators in existence. However, being completely deterministic, it is not suitable for all purposes, and is completely unsuitable for cryptographic purposes.

The functions supplied by this module are actually bound methods of a hidden instance of the `random.Random` class. You can instantiate your own instances of `Random` to get generators that don't share state. This is especially useful for multi-threaded programs, creating a different instance of `Random` for each thread, and using the `jumpahead()` method to make it likely that the generated sequences seen by each thread don't overlap.

Class `Random` can also be subclassed if you want to use a different basic generator of your own devising: in that case, override the `random()`, `seed()`, `getstate()`, `setstate()` and `jumpahead()` methods. Optionally, a new generator can supply a `getrandbits()` method — this allows `randrange()` to produce selections over an arbitrarily large range. New in version 2.4: the `getrandbits()` method. As an example of subclassing, the `random` module provides the `WichmannHill` class that implements an alternative generator in pure Python. The class provides a backward compatible way to reproduce results from earlier versions of Python, which used the Wichmann-Hill algorithm as the core generator. Note that this Wichmann-Hill generator can no longer be recommended: its period is too short by contemporary standards, and the sequence generated is known to fail some stringent randomness tests. See the references below for a recent variant that repairs these flaws. Changed in version 2.3: `MersenneTwister` replaced `Wichmann-Hill` as the default generator. The `random` module also provides the `SystemRandom` class which uses the system function `os.urandom()` to generate random numbers from sources provided by the operating system.

Bookkeeping functions:

`random.seed([x])`

Initialize the basic random number generator. Optional argument *x* can be any *hashable* object. If *x* is omitted or `None`, current system time is used; current system time is also used to initialize the generator when the module is first imported. If randomness sources are provided by the operating system, they are used instead of the system time (see the `os.urandom()` function for details on availability). Changed in version 2.4: formerly, operating system resources were not used.

`random.getstate()`

Return an object capturing the current internal state of the generator. This object can be passed to `setstate()` to restore the state. New in version 2.1. Changed in version 2.6: State values produced in Python 2.6 cannot be loaded into earlier versions.

`random.setstate(state)`

*state* should have been obtained from a previous call to `getstate()`, and `setstate()` restores the internal state of the generator to what it was at the time `getstate()` was called. New in version 2.1.

`random.jumpahead(n)`

Change the internal state to one different from and likely far away from the current state. *n* is a non-negative integer which is used to scramble the current state vector. This is most useful in multi-threaded programs, in conjunction with multiple instances of the `Random` class: `setstate()` or `seed()` can be used to force all instances into the same internal state, and then `jumpahead()` can be used to force the instances' states far apart. New in version 2.1. Changed in version 2.3: Instead of jumping to a specific state, *n* steps ahead, `jumpahead(n)` jumps to another state likely to be separated by many steps.

`random.getrandbits(k)`

Returns a python `long` int with *k* random bits. This method is supplied with the MersenneTwister generator and some other generators may also provide it as an optional part of the API. When available, `getrandbits()` enables `randrange()` to handle arbitrarily large ranges. New in version 2.4.

Functions for integers:

`random.randrange(stop)`

`random.randrange(start, stop[, step])`

Return a randomly selected element from `range(start, stop, step)`. This is equivalent to `choice(range(start, stop, step))`, but doesn't actually build a range object. New in version 1.5.2.

`random.randint(a, b)`

Return a random integer *N* such that  $a \leq N \leq b$ .

Functions for sequences:

`random.choice(seq)`

Return a random element from the non-empty sequence *seq*. If *seq* is empty, raises `IndexError`.

`random.shuffle(x[, random])`

Shuffle the sequence *x* in place. The optional argument *random* is a 0-argument function returning a random float in `[0.0, 1.0)`; by default, this is the function `random()`.

Note that for even rather small `len(x)`, the total number of permutations of *x* is larger than the period of most random number generators; this implies that most permutations of a long sequence can never be generated.

`random.sample(population, k)`

Return a *k* length list of unique elements chosen from the population sequence. Used for random sampling without replacement. New in version 2.3. Returns a new list containing elements from the population while leaving the original population unchanged. The resulting list is in selection order so that all sub-slices will also be valid random samples. This allows raffle winners (the sample) to be partitioned into grand prize and second place winners (the subslices).

Members of the population need not be *hashable* or unique. If the population contains repeats, then each occurrence is a possible selection in the sample.

To choose a sample from a range of integers, use an `xrange()` object as an argument. This is especially fast and space efficient for sampling from a large population: `sample(xrange(10000000), 60)`.

The following functions generate specific real-valued distributions. Function parameters are named after the corresponding variables in the distribution's equation, as used in common mathematical practice; most of these equations can be found in any statistics text.

`random.random()`

Return the next random floating point number in the range [0.0, 1.0).

`random.uniform(a, b)`

Return a random floating point number  $N$  such that  $a \leq N \leq b$  for  $a \leq b$  and  $b \leq N \leq a$  for  $b < a$ .

The end-point value  $b$  may or may not be included in the range depending on floating-point rounding in the equation  $a + (b-a) * \text{random}()$ .

`random.triangular(low, high, mode)`

Return a random floating point number  $N$  such that  $low \leq N \leq high$  and with the specified *mode* between those bounds. The *low* and *high* bounds default to zero and one. The *mode* argument defaults to the midpoint between the bounds, giving a symmetric distribution. New in version 2.6.

`random.betavariate(alpha, beta)`

Beta distribution. Conditions on the parameters are  $alpha > 0$  and  $beta > 0$ . Returned values range between 0 and 1.

`random.expovariate(lambd)`

Exponential distribution. *lambd* is 1.0 divided by the desired mean. It should be nonzero. (The parameter would be called "lambda", but that is a reserved word in Python.) Returned values range from 0 to positive infinity if *lambd* is positive, and from negative infinity to 0 if *lambd* is negative.

`random.gammavariate(alpha, beta)`

Gamma distribution. (Not the gamma function!) Conditions on the parameters are  $alpha > 0$  and  $beta > 0$ .

The probability distribution function is:

$$\text{pdf}(x) = \frac{x^{alpha - 1} * \text{math.exp}(-x / beta)}{\text{math.gamma}(alpha) * beta^{alpha}}$$

`random.gauss(mu, sigma)`

Gaussian distribution. *mu* is the mean, and *sigma* is the standard deviation. This is slightly faster than the `normalvariate()` function defined below.

`random.lognormvariate(mu, sigma)`

Log normal distribution. If you take the natural logarithm of this distribution, you'll get a normal distribution with mean *mu* and standard deviation *sigma*. *mu* can have any value, and *sigma* must be greater than zero.

`random.normalvariate(mu, sigma)`

Normal distribution. *mu* is the mean, and *sigma* is the standard deviation.

`random.vonmisesvariate(mu, kappa)`

*mu* is the mean angle, expressed in radians between 0 and  $2 * \pi$ , and *kappa* is the concentration parameter, which must be greater than or equal to zero. If *kappa* is equal to zero, this distribution reduces to a uniform random angle over the range 0 to  $2 * \pi$ .

`random.paretovariate(alpha)`

Pareto distribution. *alpha* is the shape parameter.

`random.weibullvariate(alpha, beta)`

Weibull distribution. *alpha* is the scale parameter and *beta* is the shape parameter.

Alternative Generators:

**class** `random.WichmannHill([seed])`

Class that implements the Wichmann-Hill algorithm as the core generator. Has all of the same methods as `Random` plus the `whseed()` method described below. Because this class is implemented in pure Python, it is not threadsafe and may require locks between calls. The period of the generator is 6,953,607,871,644 which is small enough to require care that two independent random sequences do not overlap.

`random.whseed([x])`

This is obsolete, supplied for bit-level compatibility with versions of Python prior to 2.1. See `seed()` for details. `whseed()` does not guarantee that distinct integer arguments yield distinct internal states, and can yield no more than about  $2^{24}$  distinct internal states in all.

**class** `random.SystemRandom([seed])`

Class that uses the `os.urandom()` function for generating random numbers from sources provided by the operating system. Not available on all systems. Does not rely on software state and sequences are not reproducible. Accordingly, the `seed()` and `jumpahead()` methods have no effect and are ignored. The `getstate()` and `setstate()` methods raise `NotImplementedError` if called. New in version 2.4.

Examples of basic usage:

```
>>> random.random()           # Random float x, 0.0 <= x < 1.0
0.37444887175646646
>>> random.uniform(1, 10)     # Random float x, 1.0 <= x < 10.0
1.1800146073117523
>>> random.randint(1, 10)     # Integer from 1 to 10, endpoints included
7
>>> random.randrange(0, 101, 2) # Even integer from 0 to 100
26
>>> random.choice('abcdefghij') # Choose a random element
'c'

>>> items = [1, 2, 3, 4, 5, 6, 7]
>>> random.shuffle(items)
>>> items
[7, 3, 2, 5, 6, 4, 1]

>>> random.sample([1, 2, 3, 4, 5], 3) # Choose 3 elements
[4, 1, 5]
```

**See Also:**

M. Matsumoto and T. Nishimura, “Mersenne Twister: A 623-dimensionally equidistributed uniform pseudorandom number generator”, ACM Transactions on Modeling and Computer Simulation Vol. 8, No. 1, January pp.3-30 1998.

Wichmann, B. A. & Hill, I. D., “Algorithm AS 183: An efficient and portable pseudo-random number generator”, Applied Statistics 31 (1982) 188-190.

[Complementary-Multiply-with-Carry recipe](#) for a compatible alternative random number generator with a long period and comparatively simple update operations.

## 9.7 `itertools` — Functions creating iterators for efficient looping

New in version 2.3. This module implements a number of *iterator* building blocks inspired by constructs from APL, Haskell, and SML. Each has been recast in a form suitable for Python.

The module standardizes a core set of fast, memory efficient tools that are useful by themselves or in combination. Together, they form an “iterator algebra” making it possible to construct specialized tools succinctly and efficiently in pure Python.

For instance, SML provides a tabulation tool: `tabulate(f)` which produces a sequence `f(0), f(1), ...`. The same effect can be achieved in Python by combining `imap()` and `count()` to form `imap(f, count())`.

These tools and their built-in counterparts also work well with the high-speed functions in the `operator` module. For example, the multiplication operator can be mapped across two vectors to form an efficient dot-product: `sum(imap(operator.mul, vector1, vector2))`.

### Infinite Iterators:

Iterator	Arguments	Results	Example
<code>count()</code>	<code>start,</code> <code>[step]</code>	<code>start, start+step, start+2*step, ...</code>	<code>count(10) --&gt; 10 11 12 13 14</code> ...
<code>cycle()</code>	<code>p</code>	<code>p0, p1, ... plast, p0, p1, ...</code>	<code>cycle('ABCD') --&gt; A B C D A B</code> <code>C D ...</code>
<code>repeat()</code>	<code>elem [n]</code>	<code>elem, elem, elem, ... endlessly or up to n times</code>	<code>repeat(10, 3) --&gt; 10 10 10</code>

### Iterators terminating on the shortest input sequence:

Iterator	Arguments	Results	Example
<code>chain()</code>	<code>p, q, ...</code>	<code>p0, p1, ... plast, q0, q1, ...</code>	<code>chain('ABC', 'DEF') --&gt; A B C D E F</code>
<code>compress()</code>	<code>data, selectors</code>	<code>(d[0] if s[0]), (d[1] if s[1]), ...</code>	<code>compress('ABCDEF', [1,0,1,0,1,1]) --&gt; A C E F</code>
<code>dropwhile()</code>	<code>pred, seq</code>	<code>seq[n], seq[n+1], starting when pred fails</code>	<code>dropwhile(lambda x: x&lt;5, [1,4,6,4,1]) --&gt; 6 4 1</code>
<code>groupby()</code>	<code>iterable[, keyfunc]</code>	sub-iterators grouped by value of <code>keyfunc(v)</code>	
<code>ifilter()</code>	<code>pred, seq</code>	elements of <code>seq</code> where <code>pred(elem)</code> is True	<code>ifilter(lambda x: x%2, range(10)) --&gt; 1 3 5 7 9</code>
<code>ifilterfalse()</code>	<code>pred, seq</code>	elements of <code>seq</code> where <code>pred(elem)</code> is False	<code>ifilterfalse(lambda x: x%2, range(10)) --&gt; 0 2 4 6 8</code>
<code>islice()</code>	<code>seq, [start, stop [, step]]</code>	elements from <code>seq[start:stop:step]</code>	<code>islice('ABCDEFG', 2, None) --&gt; C D E F G</code>
<code>imap()</code>	<code>func, p, q, ...</code>	<code>func(p0, q0), func(p1, q1), ...</code>	<code>imap(pow, (2,3,10), (5,2,3)) --&gt; 32 9 1000</code>
<code>starmap()</code>	<code>func, seq</code>	<code>func(*seq[0]), func(*seq[1]), ...</code>	<code>starmap(pow, [(2,5), (3,2), (10,3)]) --&gt; 32 9 1000</code>
<code>tee()</code>	<code>it, n</code>	<code>it1, it2, ... itn</code> splits one iterator into <code>n</code>	
<code>takewhile()</code>	<code>pred, seq</code>	<code>seq[0], seq[1], until pred fails</code>	<code>takewhile(lambda x: x&lt;5, [1,4,6,4,1]) --&gt; 1 4</code>
<code>izip()</code>	<code>p, q, ...</code>	<code>(p[0], q[0]), (p[1], q[1]), ...</code>	<code>izip('ABCD', 'xy') --&gt; Ax By</code>
<code>izip_longest()</code>	<code>p, q, ..., fillvalue='-'</code>	<code>(p[0], q[0]), (p[1], q[1]), ...</code>	<code>izip_longest('ABCD', 'xy', fillvalue='-') --&gt; Ax By C- D-</code>

### Combinatoric generators:

Iterator	Arguments	Results
<code>product()</code>	<code>p, q, ...</code> <code>[repeat=1]</code>	cartesian product, equivalent to a nested for-loop
<code>permutations()</code>	<code>p[, r]</code>	<code>r</code> -length tuples, all possible orderings, no repeated elements
<code>combinations()</code>	<code>p, r</code>	<code>r</code> -length tuples, in sorted order, no repeated elements
<code>combinations_with_replacement()</code>	<code>p, r</code>	<code>r</code> -length tuples, in sorted order, with repeated elements
<code>product('ABCD', repeat=2)</code>		AA AB AC AD BA BB BC BD CA CB CC CD DA DB DC DD
<code>permutations('ABCD', 2)</code>		AB AC AD BA BC BD CA CB CD DA DB DC
<code>combinations('ABCD', 2)</code>		AB AC AD BC BD CD
<code>combinations_with_replacement('ABCD', 2)</code>		AA AB AC AD BB BC BD CC CD DD

### 9.7.1 Itertool functions

The following module functions all construct and return iterators. Some provide streams of infinite length, so they should only be accessed by functions or loops that truncate the stream.

`itertools.chain(*iterables)`

Make an iterator that returns elements from the first iterable until it is exhausted, then proceeds to the next iterable, until all of the iterables are exhausted. Used for treating consecutive sequences as a single sequence. Equivalent to:

```
def chain(*iterables):
    # chain('ABC', 'DEF') --> A B C D E F
    for it in iterables:
        for element in it:
            yield element
```

`classmethod chain.from_iterable(iterable)`

Alternate constructor for `chain()`. Gets chained inputs from a single iterable argument that is evaluated lazily. Equivalent to:

```
@classmethod
def from_iterable(iterables):
    # chain.from_iterable(['ABC', 'DEF']) --> A B C D E F
    for it in iterables:
        for element in it:
            yield element
```

New in version 2.6.

`itertools.combinations(iterable, r)`

Return `r` length subsequences of elements from the input `iterable`.

Combinations are emitted in lexicographic sort order. So, if the input `iterable` is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, there will be no repeat values in each combination.

Equivalent to:

```

def combinations(iterable, r):
    # combinations('ABCD', 2) --> AB AC AD BC BD CD
    # combinations(range(4), 3) --> 012 013 023 123
    pool = tuple(iterable)
    n = len(pool)
    if r > n:
        return
    indices = range(r)
    yield tuple(pool[i] for i in indices)
    while True:
        for i in reversed(range(r)):
            if indices[i] != i + n - r:
                break
        else:
            return
        indices[i] += 1
        for j in range(i+1, r):
            indices[j] = indices[j-1] + 1
        yield tuple(pool[i] for i in indices)

```

The code for `combinations()` can be also expressed as a subsequence of `permutations()` after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```

def combinations(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in permutations(range(n), r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)

```

The number of items returned is  $n! / r! / (n-r)!$  when  $0 \leq r \leq n$  or zero when  $r > n$ . New in version 2.6.

`itertools.combinations_with_replacement` (*iterable*, *r*)

Return *r* length subsequences of elements from the input *iterable* allowing individual elements to be repeated more than once.

Combinations are emitted in lexicographic sort order. So, if the input *iterable* is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, the generated combinations will also be unique.

Equivalent to:

```

def combinations_with_replacement(iterable, r):
    # combinations_with_replacement('ABC', 2) --> AA AB AC BB BC CC
    pool = tuple(iterable)
    n = len(pool)
    if not n and r:
        return
    indices = [0] * r
    yield tuple(pool[i] for i in indices)
    while True:
        for i in reversed(range(r)):
            if indices[i] != n - 1:

```

```

        break
    else:
        return
    indices[i:] = [indices[i] + 1] * (r - i)
    yield tuple(pool[i] for i in indices)

```

The code for `combinations_with_replacement()` can be also expressed as a subsequence of `product()` after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```

def combinations_with_replacement(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in product(range(n), repeat=r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)

```

The number of items returned is  $(n+r-1)! / r! / (n-1)!$  when  $n > 0$ . New in version 2.7.

`itertools.compress(data, selectors)`

Make an iterator that filters elements from *data* returning only those that have a corresponding element in *selectors* that evaluates to `True`. Stops when either the *data* or *selectors* iterables has been exhausted. Equivalent to:

```

def compress(data, selectors):
    # compress('ABCDEF', [1,0,1,0,1,1]) --> A C E F
    return (d for d, s in izip(data, selectors) if s)

```

New in version 2.7.

`itertools.count(start=0, step=1)`

Make an iterator that returns evenly spaced values starting with *n*. Often used as an argument to `imap()` to generate consecutive data points. Also, used with `izip()` to add sequence numbers. Equivalent to:

```

def count(start=0, step=1):
    # count(10) --> 10 11 12 13 14 ...
    # count(2.5, 0.5) -> 2.5 3.0 3.5 ...
    n = start
    while True:
        yield n
        n += step

```

When counting with floating point numbers, better accuracy can sometimes be achieved by substituting multiplicative code such as: `(start + step * i for i in count())`. Changed in version 2.7: added *step* argument and allowed non-integer arguments.

`itertools.cycle(iterable)`

Make an iterator returning elements from the iterable and saving a copy of each. When the iterable is exhausted, return elements from the saved copy. Repeats indefinitely. Equivalent to:

```

def cycle(iterable):
    # cycle('ABCD') --> A B C D A B C D A B C D ...
    saved = []
    for element in iterable:
        yield element

```

```

        saved.append(element)
    while saved:
        for element in saved:
            yield element

```

Note, this member of the toolkit may require significant auxiliary storage (depending on the length of the iterable).

`itertools.dropwhile` (*predicate, iterable*)

Make an iterator that drops elements from the iterable as long as the predicate is true; afterwards, returns every element. Note, the iterator does not produce *any* output until the predicate first becomes false, so it may have a lengthy start-up time. Equivalent to:

```

def dropwhile(predicate, iterable):
    # dropwhile(lambda x: x<5, [1,4,6,4,1]) --> 6 4 1
    iterable = iter(iterable)
    for x in iterable:
        if not predicate(x):
            yield x
            break
    for x in iterable:
        yield x

```

`itertools.groupby` (*iterable*[, *key*])

Make an iterator that returns consecutive keys and groups from the *iterable*. The *key* is a function computing a key value for each element. If not specified or is `None`, *key* defaults to an identity function and returns the element unchanged. Generally, the iterable needs to already be sorted on the same key function.

The operation of `groupby()` is similar to the `uniq` filter in Unix. It generates a break or new group every time the value of the key function changes (which is why it is usually necessary to have sorted the data using the same key function). That behavior differs from SQL's GROUP BY which aggregates common elements regardless of their input order.

The returned group is itself an iterator that shares the underlying iterable with `groupby()`. Because the source is shared, when the `groupby()` object is advanced, the previous group is no longer visible. So, if that data is needed later, it should be stored as a list:

```

groups = []
uniquekeys = []
data = sorted(data, key=keyfunc)
for k, g in groupby(data, keyfunc):
    groups.append(list(g))      # Store group iterator as a list
    uniquekeys.append(k)

```

`groupby()` is equivalent to:

```

class groupby(object):
    # [k for k, g in groupby('AAAABBBCCDAABBB')] --> A B C D A B
    # [list(g) for k, g in groupby('AAAABBBCCD')] --> AAAA BBB CC D
    def __init__(self, iterable, key=None):
        if key is None:
            key = lambda x: x
        self.keyfunc = key
        self.it = iter(iterable)
        self.tgtkey = self.currkey = self.currvalue = object()

```

```
def __iter__(self):
    return self
def next(self):
    while self.currkey == self.tgtkey:
        self.currvalue = next(self.it)      # Exit on StopIteration
        self.currkey = self.keyfunc(self.currvalue)
    self.tgtkey = self.currkey
    return (self.currkey, self._grouper(self.tgtkey))
def _grouper(self, tgtkey):
    while self.currkey == tgtkey:
        yield self.currvalue
        self.currvalue = next(self.it)      # Exit on StopIteration
        self.currkey = self.keyfunc(self.currvalue)
```

New in version 2.4.

`itertools.ifilter` (*predicate*, *iterable*)

Make an iterator that filters elements from *iterable* returning only those for which the *predicate* is `True`. If *predicate* is `None`, return the items that are true. Equivalent to:

```
def ifilter(predicate, iterable):
    # ifilter(lambda x: x%2, range(10)) --> 1 3 5 7 9
    if predicate is None:
        predicate = bool
    for x in iterable:
        if predicate(x):
            yield x
```

`itertools.ifilterfalse` (*predicate*, *iterable*)

Make an iterator that filters elements from *iterable* returning only those for which the *predicate* is `False`. If *predicate* is `None`, return the items that are false. Equivalent to:

```
def ifilterfalse(predicate, iterable):
    # ifilterfalse(lambda x: x%2, range(10)) --> 0 2 4 6 8
    if predicate is None:
        predicate = bool
    for x in iterable:
        if not predicate(x):
            yield x
```

`itertools.imap` (*function*, *\*iterables*)

Make an iterator that computes the function using arguments from each of the iterables. If *function* is set to `None`, then `imap()` returns the arguments as a tuple. Like `map()` but stops when the shortest iterable is exhausted instead of filling in `None` for shorter iterables. The reason for the difference is that infinite iterator arguments are typically an error for `map()` (because the output is fully evaluated) but represent a common and useful way of supplying arguments to `imap()`. Equivalent to:

```
def imap(function, *iterables):
    # imap(pow, (2,3,10), (5,2,3)) --> 32 9 1000
    iterables = map(iter, iterables)
    while True:
        args = [next(it) for it in iterables]
        if function is None:
            yield tuple(args)
```

```

else:
    yield function(*args)

```

`itertools.islice(iterable, stop)`

`itertools.islice(iterable, start, stop[, step])`

Make an iterator that returns selected elements from the iterable. If *start* is non-zero, then elements from the iterable are skipped until *start* is reached. Afterward, elements are returned consecutively unless *step* is set higher than one which results in items being skipped. If *stop* is `None`, then iteration continues until the iterator is exhausted, if at all; otherwise, it stops at the specified position. Unlike regular slicing, `islice()` does not support negative values for *start*, *stop*, or *step*. Can be used to extract related fields from data where the internal structure has been flattened (for example, a multi-line report may list a name field on every third line). Equivalent to:

```

def islice(iterable, *args):
    # islice('ABCDEFG', 2) --> A B
    # islice('ABCDEFG', 2, 4) --> C D
    # islice('ABCDEFG', 2, None) --> C D E F G
    # islice('ABCDEFG', 0, None, 2) --> A C E G
    s = slice(*args)
    it = iter(xrange(s.start or 0, s.stop or sys.maxint, s.step or 1))
    nexti = next(it)
    for i, element in enumerate(iterable):
        if i == nexti:
            yield element
            nexti = next(it)

```

If *start* is `None`, then iteration starts at zero. If *step* is `None`, then the step defaults to one. Changed in version 2.5: accept `None` values for default *start* and *step*.

`itertools.izip(*iterables)`

Make an iterator that aggregates elements from each of the iterables. Like `zip()` except that it returns an iterator instead of a list. Used for lock-step iteration over several iterables at a time. Equivalent to:

```

def izip(*iterables):
    # izip('ABCD', 'xy') --> Ax By
    iterators = map(iter, iterables)
    while iterators:
        yield tuple(map(next, iterators))

```

Changed in version 2.4: When no iterables are specified, returns a zero length iterator instead of raising a `TypeError` exception. The left-to-right evaluation order of the iterables is guaranteed. This makes possible an idiom for clustering a data series into *n*-length groups using `izip(*[iter(s)]*n)`.

`izip()` should only be used with unequal length inputs when you don't care about trailing, unmatched values from the longer iterables. If those values are important, use `izip_longest()` instead.

`itertools.izip_longest(*iterables[, fillvalue])`

Make an iterator that aggregates elements from each of the iterables. If the iterables are of uneven length, missing values are filled-in with *fillvalue*. Iteration continues until the longest iterable is exhausted. Equivalent to:

```

class ZipExhausted(Exception):
    pass

def izip_longest(*args, **kwargs):

```

```
# izip_longest('ABCD', 'xy', fillvalue='-') --> Ax By C- D-
fillvalue = kwds.get('fillvalue')
counter = [len(args) - 1]
def sentinel():
    if not counter[0]:
        raise ZipExhausted
    counter[0] -= 1
    yield fillvalue
fillers = repeat(fillvalue)
iterators = [chain(it, sentinel(), fillers) for it in args]
try:
    while iterators:
        yield tuple(map(next, iterators))
except ZipExhausted:
    pass
```

If one of the iterables is potentially infinite, then the `izip_longest()` function should be wrapped with something that limits the number of calls (for example `islice()` or `takewhile()`). If not specified, *fillvalue* defaults to `None`. New in version 2.6.

`itertools.permutations(iterable[, r])`

Return successive *r* length permutations of elements in the *iterable*.

If *r* is not specified or is `None`, then *r* defaults to the length of the *iterable* and all possible full-length permutations are generated.

Permutations are emitted in lexicographic sort order. So, if the input *iterable* is sorted, the permutation tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, there will be no repeat values in each permutation.

Equivalent to:

```
def permutations(iterable, r=None):
    # permutations('ABCD', 2) --> AB AC AD BA BC BD CA CB CD DA DB DC
    # permutations(range(3)) --> 012 021 102 120 201 210
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
    if r > n:
        return
    indices = range(n)
    cycles = range(n, n-r, -1)
    yield tuple(pool[i] for i in indices[:r])
    while n:
        for i in reversed(range(r)):
            cycles[i] -= 1
            if cycles[i] == 0:
                indices[i:] = indices[i+1:] + indices[i:i+1]
                cycles[i] = n - i
            else:
                j = cycles[i]
                indices[i], indices[-j] = indices[-j], indices[i]
            yield tuple(pool[i] for i in indices[:r])
        break
```

```

else:
    return

```

The code for `permutations()` can be also expressed as a subsequence of `product()`, filtered to exclude entries with repeated elements (those from the same position in the input pool):

```

def permutations(iterable, r=None):
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
    for indices in product(range(n), repeat=r):
        if len(set(indices)) == r:
            yield tuple(pool[i] for i in indices)

```

The number of items returned is  $n! / (n-r)!$  when  $0 \leq r \leq n$  or zero when  $r > n$ . New in version 2.6.

`itertools.product(*iterables[, repeat])`  
 Cartesian product of input iterables.

Equivalent to nested for-loops in a generator expression. For example, `product(A, B)` returns the same as `((x,y) for x in A for y in B)`.

The nested loops cycle like an odometer with the rightmost element advancing on every iteration. This pattern creates a lexicographic ordering so that if the input's iterables are sorted, the product tuples are emitted in sorted order.

To compute the product of an iterable with itself, specify the number of repetitions with the optional `repeat` keyword argument. For example, `product(A, repeat=4)` means the same as `product(A, A, A, A)`.

This function is equivalent to the following code, except that the actual implementation does not build up intermediate results in memory:

```

def product(*args, **kwargs):
    # product('ABCD', 'xy') --> Ax Ay Bx By Cx Cy Dx Dy
    # product(range(2), repeat=3) --> 000 001 010 011 100 101 110 111
    pools = map(tuple, args) * kwargs.get('repeat', 1)
    result = [[]]
    for pool in pools:
        result = [x+[y] for x in result for y in pool]
    for prod in result:
        yield tuple(prod)

```

New in version 2.6.

`itertools.repeat(object[, times])`

Make an iterator that returns `object` over and over again. Runs indefinitely unless the `times` argument is specified. Used as argument to `imap()` for invariant function parameters. Also used with `izip()` to create constant fields in a tuple record. Equivalent to:

```

def repeat(object, times=None):
    # repeat(10, 3) --> 10 10 10
    if times is None:
        while True:
            yield object
    else:

```

```
for i in xrange(times):
    yield object
```

A common use for *repeat* is to supply a stream of constant values to *imap* or *zip*:

```
>>> list(imap(pow, xrange(10), repeat(2)))
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

`itertools.starmap` (*function, iterable*)

Make an iterator that computes the function using arguments obtained from the iterable. Used instead of `imap()` when argument parameters are already grouped in tuples from a single iterable (the data has been “pre-zipped”). The difference between `imap()` and `starmap()` parallels the distinction between `function(a,b)` and `function(*c)`. Equivalent to:

```
def starmap(function, iterable):
    # starmap(pow, [(2,5), (3,2), (10,3)]) --> 32 9 1000
    for args in iterable:
        yield function(*args)
```

Changed in version 2.6: Previously, `starmap()` required the function arguments to be tuples. Now, any iterable is allowed.

`itertools.takewhile` (*predicate, iterable*)

Make an iterator that returns elements from the iterable as long as the predicate is true. Equivalent to:

```
def takewhile(predicate, iterable):
    # takewhile(lambda x: x<5, [1,4,6,4,1]) --> 1 4
    for x in iterable:
        if predicate(x):
            yield x
        else:
            break
```

`itertools.tee` (*iterable*, *n=2*)

Return *n* independent iterators from a single iterable. Equivalent to:

```
def tee(iterable, n=2):
    it = iter(iterable)
    deque = [collections.deque() for i in range(n)]
    def gen(mydeque):
        while True:
            if not mydeque:
                newval = next(it)
            for d in deque:
                d.append(newval)
            yield mydeque.popleft()
    return tuple(gen(d) for d in deque)
```

Once `tee()` has made a split, the original *iterable* should not be used anywhere else; otherwise, the *iterable* could get advanced without the tee objects being informed.

This iterator may require significant auxiliary storage (depending on how much temporary data needs to be stored). In general, if one iterator uses most or all of the data before another iterator starts, it is faster to use `list()` instead of `tee()`. New in version 2.4.

## 9.7.2 Recipes

This section shows recipes for creating an extended toolset using the existing `itertools` as building blocks.

The extended tools offer the same high performance as the underlying toolset. The superior memory performance is kept by processing elements one at a time rather than bringing the whole iterable into memory all at once. Code volume is kept small by linking the tools together in a functional style which helps eliminate temporary variables. High speed is retained by preferring “vectorized” building blocks over the use of for-loops and *generators* which incur interpreter overhead.

```
def take(n, iterable):
    "Return first n items of the iterable as a list"
    return list(islice(iterable, n))

def tabulate(function, start=0):
    "Return function(0), function(1), ..."
    return imap(function, count(start))

def consume(iterator, n):
    "Advance the iterator n-steps ahead. If n is none, consume entirely."
    # Use functions that consume iterators at C speed.
    if n is None:
        # feed the entire iterator into a zero-length deque
        collections.deque(iterator, maxlen=0)
    else:
        # advance to the empty slice starting at position n
        next(islice(iterator, n, n), None)

def nth(iterable, n, default=None):
    "Returns the nth item or a default value"
    return next(islice(iterable, n, None), default)

def quantify(iterable, pred=bool):
    "Count how many times the predicate is true"
    return sum(imap(pred, iterable))

def padnone(iterable):
    """Returns the sequence elements and then returns None indefinitely.

    Useful for emulating the behavior of the built-in map() function.
    """
    return chain(iterable, repeat(None))

def ncycles(iterable, n):
    "Returns the sequence elements n times"
    return chain.from_iterable(repeat(tuple(iterable), n))

def dotproduct(vec1, vec2):
    return sum(imap(operator.mul, vec1, vec2))

def flatten(listOfLists):
    "Flatten one level of nesting"
    return chain.from_iterable(listOfLists)

def repeatfunc(func, times=None, *args):
```

```
"""Repeat calls to func with specified arguments.
```

```
Example: repeatfunc(random.random)
"""
```

```
if times is None:
    return starmap(func, repeat(args))
return starmap(func, repeat(args, times))
```

```
def pairwise(iterable):
    "s -> (s0,s1), (s1,s2), (s2, s3), ..."
    a, b = tee(iterable)
    next(b, None)
    return izip(a, b)
```

```
def grouper(n, iterable, fillvalue=None):
    "Collect data into fixed-length chunks or blocks"
    # grouper(3, 'ABCDEFG', 'x') --> ABC DEF Gxx
    args = [iter(iterable)] * n
    return izip_longest(fillvalue=fillvalue, *args)
```

```
def roundrobin(*iterables):
    "roundrobin('ABC', 'D', 'EF') --> A D E B F C"
    # Recipe credited to George Sakkis
    pending = len(iterables)
    nexts = cycle(iter(it).next for it in iterables)
    while pending:
        try:
            for next in nexts:
                yield next()
        except StopIteration:
            pending -= 1
            nexts = cycle(islice(nexts, pending))
```

```
def powerset(iterable):
    "powerset([1,2,3]) --> () (1,) (2,) (3,) (1,2) (1,3) (2,3) (1,2,3)"
    s = list(iterable)
    return chain.from_iterable(combinations(s, r) for r in range(len(s)+1))
```

```
def unique_everseen(iterable, key=None):
    "List unique elements, preserving order. Remember all elements ever seen."
    # unique_everseen('AAAABBBCCDAABBB') --> A B C D
    # unique_everseen('ABBCcAD', str.lower) --> A B C D
    seen = set()
    seen_add = seen.add
    if key is None:
        for element in ifilterfalse(seen.__contains__, iterable):
            seen_add(element)
            yield element
    else:
        for element in iterable:
            k = key(element)
            if k not in seen:
                seen_add(k)
                yield element
```

```

def unique_justseen(iterable, key=None):
    "List unique elements, preserving order. Remember only the element just seen."
    # unique_justseen('AAAABBBCCDAABBB') --> A B C D A B
    # unique_justseen('ABBCcAD', str.lower) --> A B C A D
    return imap(next, imap(itemgetter(1), groupby(iterable, key)))

def iter_except(func, exception, first=None):
    """ Call a function repeatedly until an exception is raised.

    Converts a call-until-exception interface to an iterator interface.
    Like __builtin__.iter(func, sentinel) but uses an exception instead
    of a sentinel to end the loop.

    Examples:
    bsddbiter = iter_except(db.next, bsddb.error, db.first)
    heapiter = iter_except(functools.partial(heapop, h), IndexError)
    dictiter = iter_except(d.popitem, KeyError)
    dequeiter = iter_except(d.popleft, IndexError)
    queueiter = iter_except(q.get_nowait, Queue.Empty)
    setiter = iter_except(s.pop, KeyError)

    """
    try:
        if first is not None:
            yield first()
        while 1:
            yield func()
    except exception:
        pass

def random_product(*args, **kwds):
    "Random selection from itertools.product(*args, **kwds)"
    pools = map(tuple, args) * kwds.get('repeat', 1)
    return tuple(random.choice(pool) for pool in pools)

def random_permutation(iterable, r=None):
    "Random selection from itertools.permutations(iterable, r)"
    pool = tuple(iterable)
    r = len(pool) if r is None else r
    return tuple(random.sample(pool, r))

def random_combination(iterable, r):
    "Random selection from itertools.combinations(iterable, r)"
    pool = tuple(iterable)
    n = len(pool)
    indices = sorted(random.sample(xrange(n), r))
    return tuple(pool[i] for i in indices)

def random_combination_with_replacement(iterable, r):
    "Random selection from itertools.combinations_with_replacement(iterable, r)"
    pool = tuple(iterable)
    n = len(pool)
    indices = sorted(random.randrange(n) for i in xrange(r))

```

```
return tuple(pool[i] for i in indices)
```

Note, many of the above recipes can be optimized by replacing global lookups with local variables defined as default values. For example, the *dotproduct* recipe can be written as:

```
def dotproduct(vec1, vec2, sum=sum, imap=imap, mul=operator.mul):
    return sum(imap(mul, vec1, vec2))
```

## 9.8 `functools` — Higher-order functions and operations on callable objects

New in version 2.5. **Source code:** [Lib/functools.py](#)

---

The `functools` module is for higher-order functions: functions that act on or return other functions. In general, any callable object can be treated as a function for the purposes of this module.

The `functools` module defines the following functions:

`functools.cmp_to_key` (*func*)

Transform an old-style comparison function to a key function. Used with tools that accept key functions (such as `sorted()`, `min()`, `max()`, `heapq.nlargest()`, `heapq.nsmallest()`, `itertools.groupby()`). This function is primarily used as a transition tool for programs being converted to Python 3 where comparison functions are no longer supported.

A comparison function is any callable that accept two arguments, compares them, and returns a negative number for less-than, zero for equality, or a positive number for greater-than. A key function is a callable that accepts one argument and returns another value that indicates the position in the desired collation sequence.

Example:

```
sorted(iterable, key=cmp_to_key(locale.strcoll)) # locale-aware sort order
```

New in version 2.7.

`functools.total_ordering` (*cls*)

Given a class defining one or more rich comparison ordering methods, this class decorator supplies the rest. This simplifies the effort involved in specifying all of the possible rich comparison operations:

The class must define one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`. In addition, the class should supply an `__eq__()` method.

For example:

```
@total_ordering
class Student:
    def __eq__(self, other):
        return ((self.lastname.lower(), self.firstname.lower()) ==
                (other.lastname.lower(), other.firstname.lower()))
    def __lt__(self, other):
        return ((self.lastname.lower(), self.firstname.lower()) <
                (other.lastname.lower(), other.firstname.lower()))
```

New in version 2.7.

`functools.reduce` (*function*, *iterable* [, *initializer* ])

This is the same function as `reduce()`. It is made available in this module to allow writing code more forward-compatible with Python 3. New in version 2.6.

`functools.partial` (*func* [, *\*args*] [, *\*\*keywords*])

Return a new `partial` object which when called will behave like *func* called with the positional arguments *args* and keyword arguments *keywords*. If more arguments are supplied to the call, they are appended to *args*. If additional keyword arguments are supplied, they extend and override *keywords*. Roughly equivalent to:

```
def partial(func, *args, **keywords):
    def newfunc(*fargs, **fkeywords):
        newkeywords = keywords.copy()
        newkeywords.update(fkeywords)
        return func(*(args + fargs), **newkeywords)
    newfunc.func = func
    newfunc.args = args
    newfunc.keywords = keywords
    return newfunc
```

The `partial()` is used for partial function application which “freezes” some portion of a function’s arguments and/or keywords resulting in a new object with a simplified signature. For example, `partial()` can be used to create a callable that behaves like the `int()` function where the *base* argument defaults to two:

```
>>> from functools import partial
>>> basetwo = partial(int, base=2)
>>> basetwo.__doc__ = 'Convert base 2 string to an int.'
>>> basetwo('10010')
18
```

`functools.update_wrapper` (*wrapper*, *wrapped* [, *assigned*] [, *updated*])

Update a *wrapper* function to look like the *wrapped* function. The optional arguments are tuples to specify which attributes of the original function are assigned directly to the matching attributes on the wrapper function and which attributes of the wrapper function are updated with the corresponding attributes from the original function. The default values for these arguments are the module level constants `WRAPPER_ASSIGNMENTS` (which assigns to the wrapper function’s `__name__`, `__module__` and `__doc__`, the documentation string) and `WRAPPER_UPDATES` (which updates the wrapper function’s `__dict__`, i.e. the instance dictionary).

The main intended use for this function is in *decorator* functions which wrap the decorated function and return the wrapper. If the wrapper function is not updated, the metadata of the returned function will reflect the wrapper definition rather than the original function definition, which is typically less than helpful.

`functools.wraps` (*wrapped* [, *assigned*] [, *updated*])

This is a convenience function for invoking `partial(update_wrapper, wrapped=wrapped, assigned=assigned, updated=updated)` as a function decorator when defining a wrapper function. For example:

```
>>> from functools import wraps
>>> def my_decorator(f):
...     @wraps(f)
...     def wrapper(*args, **kwds):
...         print 'Calling decorated function'
...         return f(*args, **kwds)
...     return wrapper
...
>>> @my_decorator
```

```
... def example():
...     """Docstring"""
...     print 'Called example function'
...
>>> example()
Calling decorated function
Called example function
>>> example.__name__
'example'
>>> example.__doc__
'Docstring'
```

Without the use of this decorator factory, the name of the `example` function would have been `'wrapper'`, and the docstring of the original `example()` would have been lost.

### 9.8.1 partial Objects

`partial` objects are callable objects created by `partial()`. They have three read-only attributes:

**`partial.func`**

A callable object or function. Calls to the `partial` object will be forwarded to `func` with new arguments and keywords.

**`partial.args`**

The leftmost positional arguments that will be prepended to the positional arguments provided to a `partial` object call.

**`partial.keywords`**

The keyword arguments that will be supplied when the `partial` object is called.

`partial` objects are like function objects in that they are callable, weak referencable, and can have attributes. There are some important differences. For instance, the `__name__` and `__doc__` attributes are not created automatically. Also, `partial` objects defined in classes behave like static methods and do not transform into bound methods during instance attribute look-up.

## 9.9 operator — Standard operators as functions

The `operator` module exports a set of efficient functions corresponding to the intrinsic operators of Python. For example, `operator.add(x, y)` is equivalent to the expression `x+y`. The function names are those used for special class methods; variants without leading and trailing `__` are also provided for convenience.

The functions fall into categories that perform object comparisons, logical operations, mathematical operations, sequence operations, and abstract type tests.

The object comparison functions are useful for all objects, and are named after the rich comparison operators they support:

```
operator.lt(a, b)
operator.le(a, b)
operator.eq(a, b)
operator.ne(a, b)
operator.ge(a, b)
operator.gt(a, b)
operator.__lt__(a, b)
operator.__le__(a, b)
```

operator.**\_\_eq\_\_**(*a*, *b*)  
 operator.**\_\_ne\_\_**(*a*, *b*)  
 operator.**\_\_ge\_\_**(*a*, *b*)  
 operator.**\_\_gt\_\_**(*a*, *b*)

Perform “rich comparisons” between *a* and *b*. Specifically, `lt(a, b)` is equivalent to `a < b`, `le(a, b)` is equivalent to `a <= b`, `eq(a, b)` is equivalent to `a == b`, `ne(a, b)` is equivalent to `a != b`, `gt(a, b)` is equivalent to `a > b` and `ge(a, b)` is equivalent to `a >= b`. Note that unlike the built-in `cmp()`, these functions can return any value, which may or may not be interpretable as a Boolean value. See *comparisons* for more information about rich comparisons. New in version 2.2.

The logical operations are also generally applicable to all objects, and support truth tests, identity tests, and boolean operations:

operator.**not\_**(*obj*)  
 operator.**\_\_not\_\_**(*obj*)

Return the outcome of `not obj`. (Note that there is no `__not__()` method for object instances; only the interpreter core defines this operation. The result is affected by the `__nonzero__()` and `__len__()` methods.)

operator.**truth**(*obj*)

Return `True` if *obj* is true, and `False` otherwise. This is equivalent to using the `bool` constructor.

operator.**is\_**(*a*, *b*)

Return `a is b`. Tests object identity. New in version 2.3.

operator.**is\_not**(*a*, *b*)

Return `a is not b`. Tests object identity. New in version 2.3.

The mathematical and bitwise operations are the most numerous:

operator.**abs**(*obj*)  
 operator.**\_\_abs\_\_**(*obj*)

Return the absolute value of *obj*.

operator.**add**(*a*, *b*)  
 operator.**\_\_add\_\_**(*a*, *b*)

Return `a + b`, for *a* and *b* numbers.

operator.**and\_**(*a*, *b*)  
 operator.**\_\_and\_\_**(*a*, *b*)

Return the bitwise and of *a* and *b*.

operator.**div**(*a*, *b*)  
 operator.**\_\_div\_\_**(*a*, *b*)

Return `a / b` when `__future__.division` is not in effect. This is also known as “classic” division.

operator.**floordiv**(*a*, *b*)  
 operator.**\_\_floordiv\_\_**(*a*, *b*)

Return `a // b`. New in version 2.2.

operator.**index**(*a*)  
 operator.**\_\_index\_\_**(*a*)

Return *a* converted to an integer. Equivalent to `a.__index__()`. New in version 2.5.

operator.**inv**(*obj*)  
 operator.**invert**(*obj*)  
 operator.**\_\_inv\_\_**(*obj*)  
 operator.**\_\_invert\_\_**(*obj*)

Return the bitwise inverse of the number *obj*. This is equivalent to `~obj`. New in version 2.0: The names `invert()` and `__invert__()`.

operator.**lshift**(*a*, *b*)

`operator.lshift(a, b)`  
Return *a* shifted left by *b*.

`operator.mod(a, b)`  
`operator.__mod__(a, b)`  
Return  $a \% b$ .

`operator.mul(a, b)`  
`operator.__mul__(a, b)`  
Return  $a * b$ , for *a* and *b* numbers.

`operator.neg(obj)`  
`operator.__neg__(obj)`  
Return *obj* negated ( $-obj$ ).

`operator.or_(a, b)`  
`operator.__or__(a, b)`  
Return the bitwise or of *a* and *b*.

`operator.pos(obj)`  
`operator.__pos__(obj)`  
Return *obj* positive ( $+obj$ ).

`operator.pow(a, b)`  
`operator.__pow__(a, b)`  
Return  $a ** b$ , for *a* and *b* numbers. New in version 2.3.

`operator.rshift(a, b)`  
`operator.__rshift__(a, b)`  
Return *a* shifted right by *b*.

`operator.sub(a, b)`  
`operator.__sub__(a, b)`  
Return  $a - b$ .

`operator.truediv(a, b)`  
`operator.__truediv__(a, b)`  
Return  $a / b$  when `__future__.division` is in effect. This is also known as “true” division. New in version 2.2.

`operator.xor(a, b)`  
`operator.__xor__(a, b)`  
Return the bitwise exclusive or of *a* and *b*.

Operations which work with sequences (some of them with mappings too) include:

`operator.concat(a, b)`  
`operator.__concat__(a, b)`  
Return  $a + b$  for *a* and *b* sequences.

`operator.contains(a, b)`  
`operator.__contains__(a, b)`  
Return the outcome of the test  $b \text{ in } a$ . Note the reversed operands. New in version 2.0: The name `__contains__()`.

`operator.countOf(a, b)`  
Return the number of occurrences of *b* in *a*.

`operator.delitem(a, b)`  
`operator.__delitem__(a, b)`  
Remove the value of *a* at index *b*.

`operator.delslice(a, b, c)`

`operator.__delslice__(a, b, c)`

Delete the slice of *a* from index *b* to index *c-1*. Deprecated since version 2.6: This function is removed in Python 3.x. Use `delitem()` with a slice index.

`operator.getitem(a, b)`

`operator.__getitem__(a, b)`

Return the value of *a* at index *b*.

`operator.getslice(a, b, c)`

`operator.__getslice__(a, b, c)`

Return the slice of *a* from index *b* to index *c-1*. Deprecated since version 2.6: This function is removed in Python 3.x. Use `getitem()` with a slice index.

`operator.indexOf(a, b)`

Return the index of the first occurrence of *b* in *a*.

`operator.repeat(a, b)`

`operator.__repeat__(a, b)`

Deprecated since version 2.7: Use `__mul__()` instead. Return *a* \* *b* where *a* is a sequence and *b* is an integer.

`operator.sequenceIncludes(...)`

Deprecated since version 2.0: Use `contains()` instead. Alias for `contains()`.

`operator.setitem(a, b, c)`

`operator.__setitem__(a, b, c)`

Set the value of *a* at index *b* to *c*.

`operator.setslice(a, b, c, v)`

`operator.__setslice__(a, b, c, v)`

Set the slice of *a* from index *b* to index *c-1* to the sequence *v*. Deprecated since version 2.6: This function is removed in Python 3.x. Use `setitem()` with a slice index.

Example use of operator functions:

```
>>> # Elementwise multiplication
>>> map(mul, [0, 1, 2, 3], [10, 20, 30, 40])
[0, 20, 60, 120]

>>> # Dot product
>>> sum(map(mul, [0, 1, 2, 3], [10, 20, 30, 40]))
200
```

Many operations have an “in-place” version. The following functions provide a more primitive access to in-place operators than the usual syntax does; for example, the *statement* `x += y` is equivalent to `x = operator.iadd(x, y)`. Another way to put it is to say that `z = operator.iadd(x, y)` is equivalent to the compound statement `z = x; z += y`.

`operator.iadd(a, b)`

`operator.__iadd__(a, b)`

`a = iadd(a, b)` is equivalent to `a += b`. New in version 2.5.

`operator.iand(a, b)`

`operator.__iand__(a, b)`

`a = iand(a, b)` is equivalent to `a &= b`. New in version 2.5.

`operator.iconcat(a, b)`

`operator.__iconcat__(a, b)`

`a = iconcat(a, b)` is equivalent to `a += b` for *a* and *b* sequences. New in version 2.5.

`operator.idiv(a, b)`

`operator.__idiv__(a, b)`

`a = idiv(a, b)` is equivalent to `a /= b` when `__future__.division` is not in effect. New in version 2.5.

`operator.ifloordiv(a, b)`

`operator.__ifloordiv__(a, b)`

`a = ifloordiv(a, b)` is equivalent to `a //= b`. New in version 2.5.

`operator.ilshift(a, b)`

`operator.__ilshift__(a, b)`

`a = ilshift(a, b)` is equivalent to `a <<= b`. New in version 2.5.

`operator.imod(a, b)`

`operator.__imod__(a, b)`

`a = imod(a, b)` is equivalent to `a %= b`. New in version 2.5.

`operator.imul(a, b)`

`operator.__imul__(a, b)`

`a = imul(a, b)` is equivalent to `a *= b`. New in version 2.5.

`operator.ior(a, b)`

`operator.__ior__(a, b)`

`a = ior(a, b)` is equivalent to `a |= b`. New in version 2.5.

`operator.ipow(a, b)`

`operator.__ipow__(a, b)`

`a = ipow(a, b)` is equivalent to `a **= b`. New in version 2.5.

`operator.irepeat(a, b)`

`operator.__irepeat__(a, b)`

Deprecated since version 2.7: Use `__imul__()` instead. `a = irepeat(a, b)` is equivalent to `a *= b` where `a` is a sequence and `b` is an integer. New in version 2.5.

`operator.irshift(a, b)`

`operator.__irshift__(a, b)`

`a = irshift(a, b)` is equivalent to `a >>= b`. New in version 2.5.

`operator.isub(a, b)`

`operator.__isub__(a, b)`

`a = isub(a, b)` is equivalent to `a -= b`. New in version 2.5.

`operator.itruediv(a, b)`

`operator.__itruediv__(a, b)`

`a = itrueidiv(a, b)` is equivalent to `a /= b` when `__future__.division` is in effect. New in version 2.5.

`operator.ixor(a, b)`

`operator.__ixor__(a, b)`

`a = ixor(a, b)` is equivalent to `a ^= b`. New in version 2.5.

The `operator` module also defines a few predicates to test the type of objects; however, these are not all reliable. It is preferable to test abstract base classes instead (see `collections` and `numbers` for details).

`operator.isCallable(obj)`

Deprecated since version 2.0: Use `isinstance(x, collections.Callable)` instead. Returns true if the object `obj` can be called like a function, otherwise it returns false. True is returned for functions, bound and unbound methods, class objects, and instance objects which support the `__call__()` method.

`operator.isMappingType(obj)`

Deprecated since version 2.7: Use `isinstance(x, collections.Mapping)` instead. Returns true if

the object *obj* supports the mapping interface. This is true for dictionaries and all instance objects defining `__getitem__()`.

`operator.isNumberType(obj)`

Deprecated since version 2.7: Use `isinstance(x, numbers.Number)` instead. Returns true if the object *obj* represents a number. This is true for all numeric types implemented in C.

`operator.isSequenceType(obj)`

Deprecated since version 2.7: Use `isinstance(x, collections.Sequence)` instead. Returns true if the object *obj* supports the sequence protocol. This returns true for all objects which define sequence methods in C, and for all instance objects defining `__getitem__()`.

The `operator` module also defines tools for generalized attribute and item lookups. These are useful for making fast field extractors as arguments for `map()`, `sorted()`, `itertools.groupby()`, or other functions that expect a function argument.

`operator.attrgetter(attr[, args...])`

Return a callable object that fetches *attr* from its operand. If more than one attribute is requested, returns a tuple of attributes. After, `f = attrgetter('name')`, the call `f(b)` returns `b.name`. After, `f = attrgetter('name', 'date')`, the call `f(b)` returns `(b.name, b.date)`. Equivalent to:

```
def attrgetter(*items):
    if len(items) == 1:
        attr = items[0]
        def g(obj):
            return resolve_attr(obj, attr)
    else:
        def g(obj):
            return tuple(resolve_attr(obj, attr) for attr in items)
    return g

def resolve_attr(obj, attr):
    for name in attr.split("."):
        obj = getattr(obj, name)
    return obj
```

The attribute names can also contain dots; after `f = attrgetter('date.month')`, the call `f(b)` returns `b.date.month`. New in version 2.4. Changed in version 2.5: Added support for multiple attributes. Changed in version 2.6: Added support for dotted attributes.

`operator.itemgetter(item[, args...])`

Return a callable object that fetches *item* from its operand using the operand's `__getitem__()` method. If multiple items are specified, returns a tuple of lookup values. Equivalent to:

```
def itemgetter(*items):
    if len(items) == 1:
        item = items[0]
        def g(obj):
            return obj[item]
    else:
        def g(obj):
            return tuple(obj[item] for item in items)
    return g
```

The items can be any type accepted by the operand's `__getitem__()` method. Dictionaries accept any hashable value. Lists, tuples, and strings accept an index or a slice:

```
>>> itemgetter(1)('ABCDEFGH')
'B'
>>> itemgetter(1,3,5)('ABCDEFGH')
('B', 'D', 'F')
>>> itemgetter(slice(2,None))('ABCDEFGH')
'CDEFGH'
```

New in version 2.4.Changed in version 2.5: Added support for multiple item extraction. Example of using `itemgetter()` to retrieve specific fields from a tuple record:

```
>>> inventory = [('apple', 3), ('banana', 2), ('pear', 5), ('orange', 1)]
>>> getcount = itemgetter(1)
>>> map(getcount, inventory)
[3, 2, 5, 1]
>>> sorted(inventory, key=getcount)
[('orange', 1), ('banana', 2), ('apple', 3), ('pear', 5)]
```

`operator.methodcaller`(*name*[, *args...*])

Return a callable object that calls the method *name* on its operand. If additional arguments and/or keyword arguments are given, they will be given to the method as well. After `f = methodcaller('name')`, the call `f(b)` returns `b.name()`. After `f = methodcaller('name', 'foo', bar=1)`, the call `f(b)` returns `b.name('foo', bar=1)`. Equivalent to:

```
def methodcaller(name, *args, **kwargs):
    def caller(obj):
        return getattr(obj, name)(*args, **kwargs)
    return caller
```

New in version 2.6.

### 9.9.1 Mapping Operators to Functions

This table shows how abstract operations correspond to operator symbols in the Python syntax and the functions in the `operator` module.

Operation	Syntax	Function
Addition	<code>a + b</code>	<code>add(a, b)</code>
Concatenation	<code>seq1 + seq2</code>	<code>concat(seq1, seq2)</code>
Containment Test	<code>obj in seq</code>	<code>contains(seq, obj)</code>
Division	<code>a / b</code>	<code>div(a, b)</code> (without <code>__future__.division</code> )
Division	<code>a / b</code>	<code>truediv(a, b)</code> (with <code>__future__.division</code> )
Division	<code>a // b</code>	<code>floordiv(a, b)</code>
Bitwise And	<code>a &amp; b</code>	<code>and_(a, b)</code>
Bitwise Exclusive Or	<code>a ^ b</code>	<code>xor(a, b)</code>
Bitwise Inversion	<code>~ a</code>	<code>invert(a)</code>
Bitwise Or	<code>a   b</code>	<code>or_(a, b)</code>
Exponentiation	<code>a ** b</code>	<code>pow(a, b)</code>
Identity	<code>a is b</code>	<code>is_(a, b)</code>
Identity	<code>a is not b</code>	<code>is_not(a, b)</code>
Indexed Assignment	<code>obj[k] = v</code>	<code>setitem(obj, k, v)</code>
Indexed Deletion	<code>del obj[k]</code>	<code>delitem(obj, k)</code>
Indexing	<code>obj[k]</code>	<code>getitem(obj, k)</code>

Continued on next page

Table 9.1 – continued from previous page

Left Shift	<code>a &lt;&lt; b</code>	<code>lshift(a, b)</code>
Modulo	<code>a % b</code>	<code>mod(a, b)</code>
Multiplication	<code>a * b</code>	<code>mul(a, b)</code>
Negation (Arithmetic)	<code>- a</code>	<code>neg(a)</code>
Negation (Logical)	<code>not a</code>	<code>not_(a)</code>
Positive	<code>+ a</code>	<code>pos(a)</code>
Right Shift	<code>a &gt;&gt; b</code>	<code>rshift(a, b)</code>
Sequence Repetition	<code>seq * i</code>	<code>repeat(seq, i)</code>
Slice Assignment	<code>seq[i:j] = values</code>	<code>setitem(seq, slice(i, j), values)</code>
Slice Deletion	<code>del seq[i:j]</code>	<code>delitem(seq, slice(i, j))</code>
Slicing	<code>seq[i:j]</code>	<code>getitem(seq, slice(i, j))</code>
String Formatting	<code>s % obj</code>	<code>mod(s, obj)</code>
Subtraction	<code>a - b</code>	<code>sub(a, b)</code>
Truth Test	<code>obj</code>	<code>truth(obj)</code>
Ordering	<code>a &lt; b</code>	<code>lt(a, b)</code>
Ordering	<code>a &lt;= b</code>	<code>le(a, b)</code>
Equality	<code>a == b</code>	<code>eq(a, b)</code>
Difference	<code>a != b</code>	<code>ne(a, b)</code>
Ordering	<code>a &gt;= b</code>	<code>ge(a, b)</code>
Ordering	<code>a &gt; b</code>	<code>gt(a, b)</code>



# FILE AND DIRECTORY ACCESS

The modules described in this chapter deal with disk files and directories. For example, there are modules for reading the properties of files, manipulating paths in a portable way, and creating temporary files. The full list of modules in this chapter is:

## 10.1 `os.path` — Common pathname manipulations

This module implements some useful functions on pathnames. To read or write files see `open()`, and for accessing the filesystem see the `os` module.

---

**Note:** On Windows, many of these functions do not properly support UNC pathnames. `splitunc()` and `ismount()` do handle them correctly.

---

**Note:** Since different operating systems have different path name conventions, there are several versions of this module in the standard library. The `os.path` module is always the path module suitable for the operating system Python is running on, and therefore usable for local paths. However, you can also import and use the individual modules if you want to manipulate a path that is *always* in one of the different formats. They all have the same interface:

- `posixpath` for UNIX-style paths
  - `ntpath` for Windows paths
  - `macpath` for old-style MacOS paths
  - `os2emxpath` for OS/2 EMX paths
- 

`os.path.abspath(path)`

Return a normalized absolutized version of the pathname *path*. On most platforms, this is equivalent to `normpath(join(os.getcwd(), path))`. New in version 1.5.2.

`os.path.basename(path)`

Return the base name of pathname *path*. This is the second half of the pair returned by `split(path)`. Note that the result of this function is different from the Unix **basename** program; where **basename** for `'/foo/bar/'` returns `'bar'`, the `basename()` function returns an empty string (`''`).

`os.path.commonprefix(list)`

Return the longest path prefix (taken character-by-character) that is a prefix of all paths in *list*. If *list* is empty, return the empty string (`''`). Note that this may return invalid paths because it works a character at a time.

`os.path.dirname` (*path*)

Return the directory name of pathname *path*. This is the first half of the pair returned by `split(path)`.

`os.path.exists` (*path*)

Return `True` if *path* refers to an existing path. Returns `False` for broken symbolic links. On some platforms, this function may return `False` if permission is not granted to execute `os.stat()` on the requested file, even if the *path* physically exists.

`os.path.lexists` (*path*)

Return `True` if *path* refers to an existing path. Returns `True` for broken symbolic links. Equivalent to `exists()` on platforms lacking `os.lstat()`. New in version 2.4.

`os.path.expanduser` (*path*)

On Unix and Windows, return the argument with an initial component of `~` or `~user` replaced by that *user*'s home directory.

On Unix, an initial `~` is replaced by the environment variable `HOME` if it is set; otherwise the current user's home directory is looked up in the password directory through the built-in module `pwd`. An initial `~user` is looked up directly in the password directory.

On Windows, `HOME` and `USERPROFILE` will be used if set, otherwise a combination of `HOMEPATH` and `HOMEDRIVE` will be used. An initial `~user` is handled by stripping the last directory component from the created user path derived above.

If the expansion fails or if the path does not begin with a tilde, the path is returned unchanged.

`os.path.expandvars` (*path*)

Return the argument with environment variables expanded. Substrings of the form `$name` or `${name}` are replaced by the value of environment variable *name*. Malformed variable names and references to non-existing variables are left unchanged.

On Windows, `%name%` expansions are supported in addition to `$name` and `${name}`.

`os.path.getatime` (*path*)

Return the time of last access of *path*. The return value is a number giving the number of seconds since the epoch (see the `time` module). Raise `os.error` if the file does not exist or is inaccessible. New in version 1.5.2. Changed in version 2.3: If `os.stat_float_times()` returns `True`, the result is a floating point number.

`os.path.getmtime` (*path*)

Return the time of last modification of *path*. The return value is a number giving the number of seconds since the epoch (see the `time` module). Raise `os.error` if the file does not exist or is inaccessible. New in version 1.5.2. Changed in version 2.3: If `os.stat_float_times()` returns `True`, the result is a floating point number.

`os.path.getctime` (*path*)

Return the system's `ctime` which, on some systems (like Unix) is the time of the last change, and, on others (like Windows), is the creation time for *path*. The return value is a number giving the number of seconds since the epoch (see the `time` module). Raise `os.error` if the file does not exist or is inaccessible. New in version 2.3.

`os.path.getsize` (*path*)

Return the size, in bytes, of *path*. Raise `os.error` if the file does not exist or is inaccessible. New in version 1.5.2.

`os.path.isabs` (*path*)

Return `True` if *path* is an absolute pathname. On Unix, that means it begins with a slash, on Windows that it begins with a (back)slash after chopping off a potential drive letter.

`os.path.isfile` (*path*)

Return `True` if *path* is an existing regular file. This follows symbolic links, so both `islink()` and `isfile()` can be true for the same path.

`os.path.isdir(path)`

Return `True` if *path* is an existing directory. This follows symbolic links, so both `islink()` and `isdir()` can be true for the same path.

`os.path.islink(path)`

Return `True` if *path* refers to a directory entry that is a symbolic link. Always `False` if symbolic links are not supported.

`os.path.ismount(path)`

Return `True` if pathname *path* is a *mount point*: a point in a file system where a different file system has been mounted. The function checks whether *path*'s parent, `path/..`, is on a different device than *path*, or whether `path/..` and *path* point to the same i-node on the same device — this should detect mount points for all Unix and POSIX variants.

`os.path.join(path1[, path2[, ...]])`

Join one or more path components intelligently. If any component is an absolute path, all previous components (on Windows, including the previous drive letter, if there was one) are thrown away, and joining continues. The return value is the concatenation of *path1*, and optionally *path2*, etc., with exactly one directory separator (`os.sep`) following each non-empty part except the last. (This means that an empty last part will result in a path that ends with a separator.) Note that on Windows, since there is a current directory for each drive, `os.path.join("c:", "foo")` represents a path relative to the current directory on drive C: (`c:foo`), not `c:\foo`.

`os.path.normcase(path)`

Normalize the case of a pathname. On Unix and Mac OS X, this returns the path unchanged; on case-insensitive filesystems, it converts the path to lowercase. On Windows, it also converts forward slashes to backward slashes.

`os.path.normpath(path)`

Normalize a pathname. This collapses redundant separators and up-level references so that `A//B`, `A/B/`, `A/./B` and `A/foo/./B` all become `A/B`.

It does not normalize the case (use `normcase()` for that). On Windows, it converts forward slashes to backward slashes. It should be understood that this may change the meaning of the path if it contains symbolic links!

`os.path.realpath(path)`

Return the canonical path of the specified filename, eliminating any symbolic links encountered in the path (if they are supported by the operating system). New in version 2.2.

`os.path.relpath(path[, start])`

Return a relative filepath to *path* either from the current directory or from an optional *start* point.

*start* defaults to `os.curdir`.

Availability: Windows, Unix. New in version 2.6.

`os.path.samefile(path1, path2)`

Return `True` if both pathname arguments refer to the same file or directory (as indicated by device number and i-node number). Raise an exception if a `os.stat()` call on either pathname fails.

Availability: Unix.

`os.path.sameopenfile(fp1, fp2)`

Return `True` if the file descriptors *fp1* and *fp2* refer to the same file.

Availability: Unix.

`os.path.samestat(stat1, stat2)`

Return `True` if the stat tuples *stat1* and *stat2* refer to the same file. These structures may have been returned by `fstat()`, `lstat()`, or `stat()`. This function implements the underlying comparison used by `samefile()` and `sameopenfile()`.

Availability: Unix.

`os.path.split(path)`

Split the pathname *path* into a pair, (*head*, *tail*) where *tail* is the last pathname component and *head* is everything leading up to that. The *tail* part will never contain a slash; if *path* ends in a slash, *tail* will be empty. If there is no slash in *path*, *head* will be empty. If *path* is empty, both *head* and *tail* are empty. Trailing slashes are stripped from *head* unless it is the root (one or more slashes only). In all cases, `join(head, tail)` returns a path to the same location as *path* (but the strings may differ).

`os.path.splitdrive(path)`

Split the pathname *path* into a pair (*drive*, *tail*) where *drive* is either a drive specification or the empty string. On systems which do not use drive specifications, *drive* will always be the empty string. In all cases, *drive* + *tail* will be the same as *path*. New in version 1.3.

`os.path.splitext(path)`

Split the pathname *path* into a pair (*root*, *ext*) such that *root* + *ext* == *path*, and *ext* is empty or begins with a period and contains at most one period. Leading periods on the basename are ignored; `.splitext('.cshrc')` returns `('.cshrc', '')`. Changed in version 2.6: Earlier versions could produce an empty root when the only period was the first character.

`os.path.splitunc(path)`

Split the pathname *path* into a pair (*unc*, *rest*) so that *unc* is the UNC mount point (such as `r'\\host\mount'`), if present, and *rest* the rest of the path (such as `r'\path\file.ext'`). For paths containing drive letters, *unc* will always be the empty string.

Availability: Windows.

`os.path.walk(path, visit, arg)`

Calls the function *visit* with arguments (*arg*, *dirname*, *names*) for each directory in the directory tree rooted at *path* (including *path* itself, if it is a directory). The argument *dirname* specifies the visited directory, the argument *names* lists the files in the directory (gotten from `os.listdir(dirname)`). The *visit* function may modify *names* to influence the set of directories visited below *dirname*, e.g. to avoid visiting certain parts of the tree. (The object referred to by *names* must be modified in place, using `del` or slice assignment.)

---

**Note:** Symbolic links to directories are not treated as subdirectories, and that `walk()` therefore will not visit them. To visit linked directories you must identify them with `os.path.islink(file)` and `os.path.isdir(file)`, and invoke `walk()` as necessary.

---

**Note:** This function is deprecated and has been removed in Python 3 in favor of `os.walk()`.

---

`os.path.supports_unicode_filenames`

True if arbitrary Unicode strings can be used as file names (within limitations imposed by the file system). New in version 2.3.

## 10.2 fileinput — Iterate over lines from multiple input streams

**Source code:** [Lib/fileinput.py](#)

---

This module implements a helper class and functions to quickly write a loop over standard input or a list of files. If you just want to read or write one file see `open()`.

The typical use is:

```
import fileinput
for line in fileinput.input():
    process(line)
```

This iterates over the lines of all files listed in `sys.argv[1:]`, defaulting to `sys.stdin` if the list is empty. If a filename is `'-'`, it is also replaced by `sys.stdin`. To specify an alternative list of filenames, pass it as the first argument to `input()`. A single file name is also allowed.

All files are opened in text mode by default, but you can override this by specifying the *mode* parameter in the call to `input()` or `FileInput()`. If an I/O error occurs during opening or reading a file, `IOError` is raised.

If `sys.stdin` is used more than once, the second and further use will return no lines, except perhaps for interactive use, or if it has been explicitly reset (e.g. using `sys.stdin.seek(0)`).

Empty files are opened and immediately closed; the only time their presence in the list of filenames is noticeable at all is when the last file opened is empty.

Lines are returned with any newlines intact, which means that the last line in a file may not have one.

You can control how files are opened by providing an opening hook via the *openhook* parameter to `fileinput.input()` or `FileInput()`. The hook must be a function that takes two arguments, *filename* and *mode*, and returns an accordingly opened file-like object. Two useful hooks are already provided by this module.

The following function is the primary interface of this module:

```
fileinput.input([files[, inplace[, backup[, mode[, openhook]]]])
```

Create an instance of the `FileInput` class. The instance will be used as global state for the functions of this module, and is also returned to use during iteration. The parameters to this function will be passed along to the constructor of the `FileInput` class. Changed in version 2.5: Added the *mode* and *openhook* parameters.

The following functions use the global state created by `fileinput.input()`; if there is no active state, `RuntimeError` is raised.

```
fileinput.filename()
```

Return the name of the file currently being read. Before the first line has been read, returns `None`.

```
fileinput.fileno()
```

Return the integer “file descriptor” for the current file. When no file is opened (before the first line and between files), returns `-1`. New in version 2.5.

```
fileinput.lineno()
```

Return the cumulative line number of the line that has just been read. Before the first line has been read, returns `0`. After the last line of the last file has been read, returns the line number of that line.

```
fileinput.filelineno()
```

Return the line number in the current file. Before the first line has been read, returns `0`. After the last line of the last file has been read, returns the line number of that line within the file.

```
fileinput.isfirstline()
```

Returns true if the line just read is the first line of its file, otherwise returns false.

```
fileinput.isstdin()
```

Returns true if the last line was read from `sys.stdin`, otherwise returns false.

```
fileinput.nextfile()
```

Close the current file so that the next iteration will read the first line from the next file (if any); lines not read from the file will not count towards the cumulative line count. The filename is not changed until after the first line of the next file has been read. Before the first line has been read, this function has no effect; it cannot be used to skip the first file. After the last line of the last file has been read, this function has no effect.

```
fileinput.close()
```

Close the sequence.

The class which implements the sequence behavior provided by the module is available for subclassing as well:

```
class fileinput.FileInput ([files[, inplace[, backup[, mode[, openhook ]]]]])
```

Class `FileInput` is the implementation; its methods `filename()`, `fileno()`, `lineno()`, `filelineno()`, `isfirstline()`, `isstdin()`, `nextfile()` and `close()` correspond to the functions of the same name in the module. In addition it has a `readline()` method which returns the next input line, and a `__getitem__()` method which implements the sequence behavior. The sequence must be accessed in strictly sequential order; random access and `readline()` cannot be mixed.

With `mode` you can specify which file mode will be passed to `open()`. It must be one of `'r'`, `'rU'`, `'U'` and `'rb'`.

The `openhook`, when given, must be a function that takes two arguments, `filename` and `mode`, and returns an accordingly opened file-like object. You cannot use `inplace` and `openhook` together. Changed in version 2.5: Added the `mode` and `openhook` parameters.

**Optional in-place filtering:** if the keyword argument `inplace=1` is passed to `fileinput.input()` or to the `FileInput` constructor, the file is moved to a backup file and standard output is directed to the input file (if a file of the same name as the backup file already exists, it will be replaced silently). This makes it possible to write a filter that rewrites its input file in place. If the `backup` parameter is given (typically as `backup='.<some extension>'`), it specifies the extension for the backup file, and the backup file remains around; by default, the extension is `'.bak'` and it is deleted when the output file is closed. In-place filtering is disabled when standard input is read.

---

**Note:** The current implementation does not work for MS-DOS 8+3 filesystems.

---

The two following opening hooks are provided by this module:

```
fileinput.hook_compressed(filename, mode)
```

Transparently opens files compressed with `gzip` and `bzip2` (recognized by the extensions `'.gz'` and `'.bz2'`) using the `gzip` and `bz2` modules. If the filename extension is not `'.gz'` or `'.bz2'`, the file is opened normally (ie, using `open()` without any decompression).

Usage example: `fi = fileinput.FileInput(openhook=fileinput.hook_compressed)`  
New in version 2.5.

```
fileinput.hook_encoded(encoding)
```

Returns a hook which opens each file with `codecs.open()`, using the given `encoding` to read the file.

Usage example: `fi = fileinput.FileInput(openhook=fileinput.hook_encoded("iso-8859-1"))`

---

**Note:** With this hook, `FileInput` might return Unicode strings depending on the specified `encoding`.

---

New in version 2.5.

## 10.3 `stat` — Interpreting `stat()` results

**Source code:** [Lib/stat.py](#)

---

The `stat` module defines constants and functions for interpreting the results of `os.stat()`, `os.fstat()` and `os.lstat()` (if they exist). For complete details about the `stat()`, `fstat()` and `lstat()` calls, consult the documentation for your system.

The `stat` module defines the following functions to test for specific file types:

`stat.S_ISDIR(mode)`

Return non-zero if the mode is from a directory.

`stat.S_ISCHR(mode)`

Return non-zero if the mode is from a character special device file.

`stat.S_ISBLK(mode)`

Return non-zero if the mode is from a block special device file.

`stat.S_ISREG(mode)`

Return non-zero if the mode is from a regular file.

`stat.S_ISFIFO(mode)`

Return non-zero if the mode is from a FIFO (named pipe).

`stat.S_ISLNK(mode)`

Return non-zero if the mode is from a symbolic link.

`stat.S_ISSOCK(mode)`

Return non-zero if the mode is from a socket.

Two additional functions are defined for more general manipulation of the file's mode:

`stat.S_IMODE(mode)`

Return the portion of the file's mode that can be set by `os.chmod()`—that is, the file's permission bits, plus the sticky bit, set-group-id, and set-user-id bits (on systems that support them).

`stat.S_IFMT(mode)`

Return the portion of the file's mode that describes the file type (used by the `S_IS*()` functions above).

Normally, you would use the `os.path.is*()` functions for testing the type of a file; the functions here are useful when you are doing multiple tests of the same file and wish to avoid the overhead of the `stat()` system call for each test. These are also useful when checking for information about a file that isn't handled by `os.path`, like the tests for block and character devices.

Example:

```
import os, sys
from stat import *

def walktree(top, callback):
    '''recursively descend the directory tree rooted at top,
       calling the callback function for each regular file'''

    for f in os.listdir(top):
        pathname = os.path.join(top, f)
        mode = os.stat(pathname).st_mode
        if S_ISDIR(mode):
            # It's a directory, recurse into it
            walktree(pathname, callback)
        elif S_ISREG(mode):
            # It's a file, call the callback function
            callback(pathname)
        else:
            # Unknown file type, print a message
            print 'Skipping %s' % pathname

def visitfile(file):
    print 'visiting', file
```

```
if __name__ == '__main__':
    walktree(sys.argv[1], visitfile)
```

All the variables below are simply symbolic indexes into the 10-tuple returned by `os.stat()`, `os.fstat()` or `os.lstat()`.

`stat.ST_MODE`  
Inode protection mode.

`stat.ST_INO`  
Inode number.

`stat.ST_DEV`  
Device inode resides on.

`stat.ST_NLINK`  
Number of links to the inode.

`stat.ST_UID`  
User id of the owner.

`stat.ST_GID`  
Group id of the owner.

`stat.ST_SIZE`  
Size in bytes of a plain file; amount of data waiting on some special files.

`stat.ST_ATIME`  
Time of last access.

`stat.ST_MTIME`  
Time of last modification.

`stat.ST_CTIME`  
The “ctime” as reported by the operating system. On some systems (like Unix) is the time of the last metadata change, and, on others (like Windows), is the creation time (see platform documentation for details).

The interpretation of “file size” changes according to the file type. For plain files this is the size of the file in bytes. For FIFOs and sockets under most flavors of Unix (including Linux in particular), the “size” is the number of bytes waiting to be read at the time of the call to `os.stat()`, `os.fstat()`, or `os.lstat()`; this can sometimes be useful, especially for polling one of these special files after a non-blocking open. The meaning of the size field for other character and block devices varies more, depending on the implementation of the underlying system call.

The variables below define the flags used in the `ST_MODE` field.

Use of the functions above is more portable than use of the first set of flags:

`stat.S_IFMT`  
Bit mask for the file type bit fields.

`stat.S_IFSOCK`  
Socket.

`stat.S_IFLNK`  
Symbolic link.

`stat.S_IFREG`  
Regular file.

`stat.S_IFBLK`  
Block device.

`stat.S_IFDIR`  
Directory.

`stat.S_IFCHR`  
Character device.

`stat.S_IFIFO`  
FIFO.

The following flags can also be used in the *mode* argument of `os.chmod()`:

`stat.S_ISUID`  
Set UID bit.

`stat.S_ISGID`  
Set-group-ID bit. This bit has several special uses. For a directory it indicates that BSD semantics is to be used for that directory: files created there inherit their group ID from the directory, not from the effective group ID of the creating process, and directories created there will also get the `S_ISGID` bit set. For a file that does not have the group execution bit (`S_IXGRP`) set, the set-group-ID bit indicates mandatory file/record locking (see also `S_ENFMT`).

`stat.S_ISVTX`  
Sticky bit. When this bit is set on a directory it means that a file in that directory can be renamed or deleted only by the owner of the file, by the owner of the directory, or by a privileged process.

`stat.S_IRWXU`  
Mask for file owner permissions.

`stat.S_IRUSR`  
Owner has read permission.

`stat.S_IWUSR`  
Owner has write permission.

`stat.S_IXUSR`  
Owner has execute permission.

`stat.S_IRWXG`  
Mask for group permissions.

`stat.S_IRGRP`  
Group has read permission.

`stat.S_IWGRP`  
Group has write permission.

`stat.S_IXGRP`  
Group has execute permission.

`stat.S_IRWXO`  
Mask for permissions for others (not in group).

`stat.S_IROTH`  
Others have read permission.

`stat.S_IWOTH`  
Others have write permission.

`stat.S_IXOTH`  
Others have execute permission.

`stat.S_ENFMT`  
System V file locking enforcement. This flag is shared with `S_ISGID`: file/record locking is enforced on files that do not have the group execution bit (`S_IXGRP`) set.

`stat.S_IREAD`  
Unix V7 synonym for `S_IRUSR`.

`stat.S_IWRITE`  
Unix V7 synonym for `S_IWUSR`.

`stat.S_IXEXEC`  
Unix V7 synonym for `S_IXUSR`.

The following flags can be used in the *flags* argument of `os.chflags()`:

`stat.UF_NODUMP`  
Do not dump the file.

`stat.UF_IMMUTABLE`  
The file may not be changed.

`stat.UF_APPEND`  
The file may only be appended to.

`stat.UF_OPAQUE`  
The directory is opaque when viewed through a union stack.

`stat.UF_NOUNLINK`  
The file may not be renamed or deleted.

`stat.UF_COMPRESSED`  
The file is stored compressed (Mac OS X 10.6+).

`stat.UF_HIDDEN`  
The file should not be displayed in a GUI (Mac OS X 10.5+).

`stat.SF_ARCHIVED`  
The file may be archived.

`stat.SF_IMMUTABLE`  
The file may not be changed.

`stat.SF_APPEND`  
The file may only be appended to.

`stat.SF_NOUNLINK`  
The file may not be renamed or deleted.

`stat.SF_SNAPSHOT`  
The file is a snapshot file.

See the \*BSD or Mac OS systems man page *chflags(2)* for more information.

## 10.4 `statvfs` — Constants used with `os.statvfs()`

Deprecated since version 2.6: The `statvfs` module has been removed in Python 3. The `statvfs` module defines constants so interpreting the result if `os.statvfs()`, which returns a tuple, can be made without remembering “magic numbers.” Each of the constants defined in this module is the *index* of the entry in the tuple returned by `os.statvfs()` that contains the specified information.

`statvfs.F_BSIZE`  
Preferred file system block size.

`statvfs.F_FRSIZE`  
Fundamental file system block size.

`statvfs.F_BLOCKS`  
Total number of blocks in the filesystem.

`statvfs.F_BFREE`  
Total number of free blocks.

`statvfs.F_BAVAIL`  
Free blocks available to non-super user.

`statvfs.F_FILES`  
Total number of file nodes.

`statvfs.F_FFREE`  
Total number of free file nodes.

`statvfs.F_FAVAIL`  
Free nodes available to non-super user.

`statvfs.F_FLAG`  
Flags. System dependent: see `statvfs()` man page.

`statvfs.F_NAMEMAX`  
Maximum file name length.

## 10.5 filecmp — File and Directory Comparisons

Source code: [Lib/filecmp.py](#)

The `filecmp` module defines functions to compare files and directories, with various optional time/correctness trade-offs. For comparing files, see also the `difflib` module.

The `filecmp` module defines the following functions:

`filecmp.cmp(f1, f2[, shallow])`

Compare the files named *f1* and *f2*, returning `True` if they seem equal, `False` otherwise.

Unless *shallow* is given and is `false`, files with identical `os.stat()` signatures are taken to be equal.

Files that were compared using this function will not be compared again unless their `os.stat()` signature changes.

Note that no external programs are called from this function, giving it portability and efficiency.

`filecmp.cmpfiles(dir1, dir2, common[, shallow])`

Compare the files in the two directories *dir1* and *dir2* whose names are given by *common*.

Returns three lists of file names: *match*, *mismatch*, *errors*. *match* contains the list of files that match, *mismatch* contains the names of those that don't, and *errors* lists the names of files which could not be compared. Files are listed in *errors* if they don't exist in one of the directories, the user lacks permission to read them or if the comparison could not be done for some other reason.

The *shallow* parameter has the same meaning and default value as for `filecmp.cmp()`.

For example, `cmpfiles('a', 'b', ['c', 'd/e'])` will compare *a/c* with *b/c* and *a/d/e* with *b/d/e*. *'c'* and *'d/e'* will each be in one of the three returned lists.

Example:

```
>>> import filecmp
>>> filecmp.cmp('undoc.rst', 'undoc.rst')
True
>>> filecmp.cmp('undoc.rst', 'index.rst')
False
```

## 10.5.1 The `dircmp` class

`dircmp` instances are built using this constructor:

```
class filecmp.dircmp(a, b[, ignore[, hide ]])
```

Construct a new directory comparison object, to compare the directories *a* and *b*. *ignore* is a list of names to ignore, and defaults to ['RCS', 'CVS', 'tags']. *hide* is a list of names to hide, and defaults to [os.curdir, os.pardir].

The `dircmp` class compares files by doing *shallow* comparisons as described for `filecmp.cmp()`.

The `dircmp` class provides the following methods:

**report()**

Print (to `sys.stdout`) a comparison between *a* and *b*.

**report\_partial\_closure()**

Print a comparison between *a* and *b* and common immediate subdirectories.

**report\_full\_closure()**

Print a comparison between *a* and *b* and common subdirectories (recursively).

The `dircmp` class offers a number of interesting attributes that may be used to get various bits of information about the directory trees being compared.

Note that via `__getattr__()` hooks, all attributes are computed lazily, so there is no speed penalty if only those attributes which are lightweight to compute are used.

**left**

The directory *a*.

**right**

The directory *b*.

**left\_list**

Files and subdirectories in *a*, filtered by *hide* and *ignore*.

**right\_list**

Files and subdirectories in *b*, filtered by *hide* and *ignore*.

**common**

Files and subdirectories in both *a* and *b*.

**left\_only**

Files and subdirectories only in *a*.

**right\_only**

Files and subdirectories only in *b*.

**common\_dirs**

Subdirectories in both *a* and *b*.

**common\_files**

Files in both *a* and *b*

**common\_funny**

Names in both *a* and *b*, such that the type differs between the directories, or names for which `os.stat()` reports an error.

**same\_files**

Files which are identical in both *a* and *b*, using the class's file comparison operator.

**diff\_files**

Files which are in both *a* and *b*, whose contents differ according to the class's file comparison operator.

**funny\_files**

Files which are in both *a* and *b*, but could not be compared.

**subdirs**

A dictionary mapping names in `common_dirs` to `dircmp` objects.

Here is a simplified example of using the `subdirs` attribute to search recursively through two directories to show common different files:

```
>>> from filecmp import dircmp
>>> def print_diff_files(dcmp):
...     for name in dcmp.diff_files:
...         print "diff_file %s found in %s and %s" % (name, dcmp.left,
...           dcmp.right)
...     for sub_dcmp in dcmp.subdirs.values():
...         print_diff_files(sub_dcmp)
...
>>> dcmp = dircmp('dir1', 'dir2')
>>> print_diff_files(dcmp)
```

## 10.6 tempfile — Generate temporary files and directories

Source code: [Lib/tempfile.py](#)

This module generates temporary files and directories. It works on all supported platforms.

In version 2.3 of Python, this module was overhauled for enhanced security. It now provides three new functions, `NamedTemporaryFile()`, `mkstemp()`, and `mkdtemp()`, which should eliminate all remaining need to use the insecure `mktemp()` function. Temporary file names created by this module no longer contain the process ID; instead a string of six random characters is used.

Also, all the user-callable functions now take additional arguments which allow direct control over the location and name of temporary files. It is no longer necessary to use the global `tempdir` and `template` variables. To maintain backward compatibility, the argument order is somewhat odd; it is recommended to use keyword arguments for clarity.

The module defines the following user-callable functions:

```
tempfile.TemporaryFile([mode='w+b', bufsize=-1, suffix='', prefix='tmp', dir=None]))
```

Return a file-like object that can be used as a temporary storage area. The file is created using `mkstemp()`. It will be destroyed as soon as it is closed (including an implicit close when the object is garbage collected). Under Unix, the directory entry for the file is removed immediately after the file is created. Other platforms do not support this; your code should not rely on a temporary file created using this function having or not having a visible name in the file system.

The `mode` parameter defaults to `'w+b'` so that the file created can be read and written without being closed. Binary mode is used so that it behaves consistently on all platforms without regard for the data that is stored. `bufsize` defaults to `-1`, meaning that the operating system default is used.

The *dir*, *prefix* and *suffix* parameters are passed to `mkstemp()`.

The returned object is a true file object on POSIX platforms. On other platforms, it is a file-like object whose `file` attribute is the underlying true file object. This file-like object can be used in a `with` statement, just like a normal file.

```
tempfile.NamedTemporaryFile([mode='w+b', bufsize=-1, suffix='', prefix='tmp', dir=None,
                             delete=True])
```

This function operates exactly as `TemporaryFile()` does, except that the file is guaranteed to have a visible name in the file system (on Unix, the directory entry is not unlinked). That name can be retrieved from the `name` attribute of the file object. Whether the name can be used to open the file a second time, while the named temporary file is still open, varies across platforms (it can be so used on Unix; it cannot on Windows NT or later). If *delete* is true (the default), the file is deleted as soon as it is closed.

The returned object is always a file-like object whose `file` attribute is the underlying true file object. This file-like object can be used in a `with` statement, just like a normal file. New in version 2.3. New in version 2.6: The *delete* parameter.

```
tempfile.SpooledTemporaryFile([max_size=0, mode='w+b', bufsize=-1, suffix='',
                               prefix='tmp', dir=None])
```

This function operates exactly as `TemporaryFile()` does, except that data is spooled in memory until the file size exceeds *max\_size*, or until the file's `fileno()` method is called, at which point the contents are written to disk and operation proceeds as with `TemporaryFile()`.

The resulting file has one additional method, `rollover()`, which causes the file to roll over to an on-disk file regardless of its size.

The returned object is a file-like object whose `_file` attribute is either a `StringIO` object or a true file object, depending on whether `rollover()` has been called. This file-like object can be used in a `with` statement, just like a normal file. New in version 2.6.

```
tempfile.mkstemp([suffix='', prefix='tmp', dir=None, text=False])
```

Creates a temporary file in the most secure manner possible. There are no race conditions in the file's creation, assuming that the platform properly implements the `os.O_EXCL` flag for `os.open()`. The file is readable and writable only by the creating user ID. If the platform uses permission bits to indicate whether a file is executable, the file is executable by no one. The file descriptor is not inherited by child processes.

Unlike `TemporaryFile()`, the user of `mkstemp()` is responsible for deleting the temporary file when done with it.

If *suffix* is specified, the file name will end with that suffix, otherwise there will be no suffix. `mkstemp()` does not put a dot between the file name and the suffix; if you need one, put it at the beginning of *suffix*.

If *prefix* is specified, the file name will begin with that prefix; otherwise, a default prefix is used.

If *dir* is specified, the file will be created in that directory; otherwise, a default directory is used. The default directory is chosen from a platform-dependent list, but the user of the application can control the directory location by setting the `TMPDIR`, `TEMP` or `TMP` environment variables. There is thus no guarantee that the generated filename will have any nice properties, such as not requiring quoting when passed to external commands via `os.popen()`.

If *text* is specified, it indicates whether to open the file in binary mode (the default) or text mode. On some platforms, this makes no difference.

`mkstemp()` returns a tuple containing an OS-level handle to an open file (as would be returned by `os.open()`) and the absolute pathname of that file, in that order. New in version 2.3.

```
tempfile.mkdtemp([suffix='', prefix='tmp', dir=None])
```

Creates a temporary directory in the most secure manner possible. There are no race conditions in the directory's creation. The directory is readable, writable, and searchable only by the creating user ID.

The user of `mkdtemp()` is responsible for deleting the temporary directory and its contents when done with it.

The *prefix*, *suffix*, and *dir* arguments are the same as for `mkstemp()`.

`mkdtemp()` returns the absolute pathname of the new directory. New in version 2.3.

`tempfile.mktemp([suffix='',[prefix='tmp',[dir=None]]])`

Deprecated since version 2.3: Use `mkstemp()` instead. Return an absolute pathname of a file that did not exist at the time the call is made. The *prefix*, *suffix*, and *dir* arguments are the same as for `mkstemp()`.

**Warning:** Use of this function may introduce a security hole in your program. By the time you get around to doing anything with the file name it returns, someone else may have beaten you to the punch. `mktemp()` usage can be replaced easily with `NamedTemporaryFile()`, passing it the `delete=False` parameter:

```
>>> f = NamedTemporaryFile(delete=False)
>>> f
<open file '<fdopen>', mode 'w+b' at 0x384698>
>>> f.name
'/var/folders/5q/5qTPn6xq2RaWqk+1Ytw3-U+++TI/-Tmp-/tmpG7V1Y0'
>>> f.write("Hello World!\n")
>>> f.close()
>>> os.unlink(f.name)
>>> os.path.exists(f.name)
False
```

The module uses two global variables that tell it how to construct a temporary name. They are initialized at the first call to any of the functions above. The caller may change them, but this is discouraged; use the appropriate function arguments, instead.

`tempfile.tempdir`

When set to a value other than `None`, this variable defines the default value for the *dir* argument to all the functions defined in this module.

If `tempdir` is unset or `None` at any call to any of the above functions, Python searches a standard list of directories and sets `tempdir` to the first one which the calling user can create files in. The list is:

- 1.The directory named by the `TMPDIR` environment variable.
- 2.The directory named by the `TEMP` environment variable.
- 3.The directory named by the `TMP` environment variable.
- 4.A platform-specific location:
  - On RiscOS, the directory named by the `Wimp$ScrapDir` environment variable.
  - On Windows, the directories `C:\TEMP`, `C:\TMP`, `\TEMP`, and `\TMP`, in that order.
  - On all other platforms, the directories `/tmp`, `/var/tmp`, and `/usr/tmp`, in that order.
- 5.As a last resort, the current working directory.

`tempfile.gettempdir()`

Return the directory currently selected to create temporary files in. If `tempdir` is not `None`, this simply returns its contents; otherwise, the search described above is performed, and the result returned. New in version 2.3.

`tempfile.template`

Deprecated since version 2.0: Use `gettempprefix()` instead. When set to a value other than `None`, this variable defines the prefix of the final component of the filenames returned by `mktemp()`. A string of six random letters and digits is appended to the prefix to make the filename unique. The default prefix is `tmp`.

Older versions of this module used to require that `template` be set to `None` after a call to `os.fork()`; this has not been necessary since version 1.5.2.

`tempfile.gettemprefix()`

Return the filename prefix used to create temporary files. This does not contain the directory component. Using this function is preferred over reading the `template` variable directly. New in version 1.5.2.

## 10.7 `glob` — Unix style pathname pattern expansion

Source code: [Lib/glob.py](#)

---

The `glob` module finds all the pathnames matching a specified pattern according to the rules used by the Unix shell. No tilde expansion is done, but `*`, `?`, and character ranges expressed with `[]` will be correctly matched. This is done by using the `os.listdir()` and `fnmatch.fnmatch()` functions in concert, and not by actually invoking a subshell. (For tilde and shell variable expansion, use `os.path.expanduser()` and `os.path.expandvars()`.)

`glob.glob(pathname)`

Return a possibly-empty list of path names that match *pathname*, which must be a string containing a path specification. *pathname* can be either absolute (like `/usr/src/Python-1.5/Makefile`) or relative (like `../../Tools/*/*.gif`), and can contain shell-style wildcards. Broken symlinks are included in the results (as in the shell).

`glob.iglob(pathname)`

Return an *iterator* which yields the same values as `glob()` without actually storing them all simultaneously. New in version 2.5.

For example, consider a directory containing only the following files: `1.gif`, `2.txt`, and `card.gif`. `glob()` will produce the following results. Notice how any leading components of the path are preserved.

```
>>> import glob
>>> glob.glob('./[0-9].*')
['./1.gif', './2.txt']
>>> glob.glob('*.*gif')
['1.gif', 'card.gif']
>>> glob.glob('?.*gif')
['1.gif']
```

See Also:

Module `fnmatch` Shell-style filename (not path) expansion

## 10.8 `fnmatch` — Unix filename pattern matching

Source code: [Lib/fnmatch.py](#)

---

This module provides support for Unix shell-style wildcards, which are *not* the same as regular expressions (which are documented in the `re` module). The special characters used in shell-style wildcards are:

Pattern	Meaning
<code>*</code>	matches everything
<code>?</code>	matches any single character
<code>[seq]</code>	matches any character in <i>seq</i>
<code>[!seq]</code>	matches any character not in <i>seq</i>

Note that the filename separator ('/' on Unix) is *not* special to this module. See module `glob` for pathname expansion (`glob` uses `fnmatch()` to match pathname segments). Similarly, filenames starting with a period are not special for this module, and are matched by the `*` and `?` patterns.

`fnmatch.fnmatch` (*filename*, *pattern*)

Test whether the *filename* string matches the *pattern* string, returning `True` or `False`. If the operating system is case-insensitive, then both parameters will be normalized to all lower- or upper-case before the comparison is performed. `fnmatchcase()` can be used to perform a case-sensitive comparison, regardless of whether that's standard for the operating system.

This example will print all file names in the current directory with the extension `.txt`:

```
import fnmatch
import os

for file in os.listdir('.'):
    if fnmatch.fnmatch(file, '*.txt'):
        print file
```

`fnmatch.fnmatchcase` (*filename*, *pattern*)

Test whether *filename* matches *pattern*, returning `True` or `False`; the comparison is case-sensitive.

`fnmatch.filter` (*names*, *pattern*)

Return the subset of the list of *names* that match *pattern*. It is the same as `[n for n in names if fnmatch(n, pattern)]`, but implemented more efficiently. New in version 2.2.

`fnmatch.translate` (*pattern*)

Return the shell-style *pattern* converted to a regular expression.

Be aware there is no way to quote meta-characters.

Example:

```
>>> import fnmatch, re
>>>
>>> regex = fnmatch.translate('*.txt')
>>> regex
'.*\\.txt$'
>>> reobj = re.compile(regex)
>>> reobj.match('foobar.txt')
<_sre.SRE_Match object at 0x...>
```

**See Also:**

**Module `glob`** Unix shell-style path expansion.

## 10.9 `linecache` — Random access to text lines

**Source code:** [Lib/linecache.py](#)

The `linecache` module allows one to get any line from any file, while attempting to optimize internally, using a cache, the common case where many lines are read from a single file. This is used by the `traceback` module to retrieve source lines for inclusion in the formatted traceback.

The `linecache` module defines the following functions:

`linecache.getline(filename, lineno[, module_globals])`

Get line *lineno* from file named *filename*. This function will never raise an exception — it will return "" on errors (the terminating newline character will be included for lines that are found).

If a file named *filename* is not found, the function will look for it in the module search path, `sys.path`, after first checking for a [PEP 302](#) `__loader__` in *module\_globals*, in case the module was imported from a zipfile or other non-filesystem import source. New in version 2.5: The *module\_globals* parameter was added.

`linecache.clearcache()`

Clear the cache. Use this function if you no longer need lines from files previously read using `getline()`.

`linecache.checkcache([filename])`

Check the cache for validity. Use this function if files in the cache may have changed on disk, and you require the updated version. If *filename* is omitted, it will check all the entries in the cache.

Example:

```
>>> import linecache
>>> linecache.getline('/etc/passwd', 4)
'sys:x:3:3:sys:/dev:/bin/sh\n'
```

## 10.10 `shutil` — High-level file operations

Source code: [Lib/shutil.py](#)

---

The `shutil` module offers a number of high-level operations on files and collections of files. In particular, functions are provided which support file copying and removal. For operations on individual files, see also the `os` module.

**Warning:** Even the higher-level file copying functions (`shutil.copy()`, `shutil.copy2()`) can't copy all file metadata.

On POSIX platforms, this means that file owner and group are lost as well as ACLs. On Mac OS, the resource fork and other metadata are not used. This means that resources will be lost and file type and creator codes will not be correct. On Windows, file owners, ACLs and alternate data streams are not copied.

### 10.10.1 Directory and files operations

`shutil.copyfileobj(fsrc, fdst[, length])`

Copy the contents of the file-like object *fsrc* to the file-like object *fdst*. The integer *length*, if given, is the buffer size. In particular, a negative *length* value means to copy the data without looping over the source data in chunks; by default the data is read in chunks to avoid uncontrolled memory consumption. Note that if the current file position of the *fsrc* object is not 0, only the contents from the current file position to the end of the file will be copied.

`shutil.copyfile(src, dst)`

Copy the contents (no metadata) of the file named *src* to a file named *dst*. *dst* must be the complete target file name; look at `shutil.copy()` for a copy that accepts a target directory path. If *src* and *dst* are the same files, `Error` is raised. The destination location must be writable; otherwise, an `IOError` exception will be raised. If *dst* already exists, it will be replaced. Special files such as character or block devices and pipes cannot be copied with this function. *src* and *dst* are path names given as strings.

`shutil.copymode(src, dst)`

Copy the permission bits from *src* to *dst*. The file contents, owner, and group are unaffected. *src* and *dst* are path names given as strings.

`shutil.copystat(src, dst)`

Copy the permission bits, last access time, last modification time, and flags from *src* to *dst*. The file contents, owner, and group are unaffected. *src* and *dst* are path names given as strings.

`shutil.copy(src, dst)`

Copy the file *src* to the file or directory *dst*. If *dst* is a directory, a file with the same basename as *src* is created (or overwritten) in the directory specified. Permission bits are copied. *src* and *dst* are path names given as strings.

`shutil.copy2(src, dst)`

Similar to `shutil.copy()`, but metadata is copied as well – in fact, this is just `shutil.copy()` followed by `copystat()`. This is similar to the Unix command `cp -p`.

`shutil.ignore_patterns(*patterns)`

This factory function creates a function that can be used as a callable for `copytree()`'s *ignore* argument, ignoring files and directories that match one of the glob-style *patterns* provided. See the example below. New in version 2.6.

`shutil.copytree(src, dst, symlinks=False, ignore=None)`

Recursively copy an entire directory tree rooted at *src*. The destination directory, named by *dst*, must not already exist; it will be created as well as missing parent directories. Permissions and times of directories are copied with `copystat()`, individual files are copied using `shutil.copy2()`.

If *symlinks* is true, symbolic links in the source tree are represented as symbolic links in the new tree, but the metadata of the original links is NOT copied; if false or omitted, the contents and metadata of the linked files are copied to the new tree.

If *ignore* is given, it must be a callable that will receive as its arguments the directory being visited by `copytree()`, and a list of its contents, as returned by `os.listdir()`. Since `copytree()` is called recursively, the *ignore* callable will be called once for each directory that is copied. The callable must return a sequence of directory and file names relative to the current directory (i.e. a subset of the items in its second argument); these names will then be ignored in the copy process. `ignore_patterns()` can be used to create such a callable that ignores names based on glob-style patterns.

If exception(s) occur, an `Error` is raised with a list of reasons.

The source code for this should be considered an example rather than the ultimate tool. Changed in version 2.3: `Error` is raised if any exceptions occur during copying, rather than printing a message. Changed in version 2.5: Create intermediate directories needed to create *dst*, rather than raising an error. Copy permissions and times of directories using `copystat()`. Changed in version 2.6: Added the *ignore* argument to be able to influence what is being copied.

`shutil.rmtree(path[, ignore_errors[, onerror]])`

Delete an entire directory tree; *path* must point to a directory (but not a symbolic link to a directory). If *ignore\_errors* is true, errors resulting from failed removals will be ignored; if false or omitted, such errors are handled by calling a handler specified by *onerror* or, if that is omitted, they raise an exception.

If *onerror* is provided, it must be a callable that accepts three parameters: *function*, *path*, and *excinfo*. The first parameter, *function*, is the function which raised the exception; it will be `os.path.islink()`, `os.listdir()`, `os.remove()` or `os.rmdir()`. The second parameter, *path*, will be the path name passed to *function*. The third parameter, *excinfo*, will be the exception information return by `sys.exc_info()`. Exceptions raised by *onerror* will not be caught. Changed in version 2.6: Explicitly check for *path* being a symbolic link and raise `OSError` in that case.

`shutil.move(src, dst)`

Recursively move a file or directory (*src*) to another location (*dst*).

If the destination is a directory or a symlink to a directory, then *src* is moved inside that directory.

The destination directory must not already exist. If the destination already exists but is not a directory, it may be overwritten depending on `os.rename()` semantics.

If the destination is on the current filesystem, then `os.rename()` is used. Otherwise, `src` is copied (using `shutil.copy2()`) to `dst` and then removed. New in version 2.3.

### exception `shutil.Error`

This exception collects exceptions that are raised during a multi-file operation. For `copytree()`, the exception argument is a list of 3-tuples (`srcname, dstname, exception`). New in version 2.3.

### copytree example

This example is the implementation of the `copytree()` function, described above, with the docstring omitted. It demonstrates many of the other functions provided by this module.

```
def copytree(src, dst, symlinks=False, ignore=None):
    names = os.listdir(src)
    if ignore is not None:
        ignored_names = ignore(src, names)
    else:
        ignored_names = set()

    os.makedirs(dst)
    errors = []
    for name in names:
        if name in ignored_names:
            continue
        srcname = os.path.join(src, name)
        dstname = os.path.join(dst, name)
        try:
            if symlinks and os.path.islink(srcname):
                linkto = os.readlink(srcname)
                os.symlink(linkto, dstname)
            elif os.path.isdir(srcname):
                copytree(srcname, dstname, symlinks, ignore)
            else:
                copy2(srcname, dstname)
                # XXX What about devices, sockets etc.?
        except (IOError, os.error), why:
            errors.append((srcname, dstname, str(why)))
        # catch the Error from the recursive copytree so that we can
        # continue with other files
        except Error, err:
            errors.extend(err.args[0])
    try:
        copystat(src, dst)
    except WindowsError:
        # can't copy file access times on Windows
        pass
    except OSError, why:
        errors.extend((src, dst, str(why)))
    if errors:
        raise Error(errors)
```

Another example that uses the `ignore_patterns()` helper:

```
from shutil import copytree, ignore_patterns
```

```
copytree(source, destination, ignore=ignore_patterns('*.pyc', 'tmp*'))
```

This will copy everything except `.pyc` files and files or directories whose name starts with `tmp`.

Another example that uses the `ignore` argument to add a logging call:

```
from shutil import copytree
import logging

def _logpath(path, names):
    logging.info('Working in %s' % path)
    return [] # nothing will be ignored

copytree(source, destination, ignore=_logpath)
```

## 10.10.2 Archiving operations

High-level utilities to create and read compressed and archived files are also provided. They rely on the `zipfile` and `tarfile` modules.

```
shutil.make_archive(base_name, format[, root_dir[, base_dir[, verbose[, dry_run[, owner[, group[,
    logger]]]]]])
```

Create an archive file (eg. zip or tar) and returns its name.

`base_name` is the name of the file to create, including the path, minus any format-specific extension. `format` is the archive format: one of “zip”, “tar”, “bztar” or “gztar”.

`root_dir` is a directory that will be the root directory of the archive; ie. we typically `chdir` into `root_dir` before creating the archive.

`base_dir` is the directory where we start archiving from; ie. `base_dir` will be the common prefix of all files and directories in the archive.

`root_dir` and `base_dir` both default to the current directory.

`owner` and `group` are used when creating a tar archive. By default, uses the current owner and group.

`logger` must be an object compatible with [PEP 282](#), usually an instance of `logging.Logger`. New in version 2.7.

```
shutil.get_archive_formats()
```

Return a list of supported formats for archiving. Each element of the returned sequence is a tuple (name, description)

By default `shutil` provides these formats:

- gztar*: gzip’ed tar-file
- bztar*: bzip2’ed tar-file
- tar*: uncompressed tar file
- zip*: ZIP file

You can register new formats or provide your own archiver for any existing formats, by using `register_archive_format()`. New in version 2.7.

```
shutil.register_archive_format(name, function[, extra_args[, description]])
```

Register an archiver for the format `name`. `function` is a callable that will be used to invoke the archiver.

If given, `extra_args` is a sequence of (name, value) that will be used as extra keywords arguments when the archiver callable is used.

*description* is used by `get_archive_formats()` which returns the list of archivers. Defaults to an empty list. New in version 2.7.

`shutil.unregister_archive_format(name)`

Remove the archive format *name* from the list of supported formats. New in version 2.7.

### Archiving example

In this example, we create a gzip'ed tar-file archive containing all files found in the `.ssh` directory of the user:

```
>>> from shutil import make_archive
>>> import os
>>> archive_name = os.path.expanduser(os.path.join('~', 'myarchive'))
>>> root_dir = os.path.expanduser(os.path.join('~', '.ssh'))
>>> make_archive(archive_name, 'gztar', root_dir)
'/Users/tarek/myarchive.tar.gz'
```

The resulting archive contains:

```
$ tar -tzvf /Users/tarek/myarchive.tar.gz
drwx----- tarek/staff      0 2010-02-01 16:23:40 ./
-rw-r--r--  tarek/staff     609 2008-06-09 13:26:54 ./authorized_keys
-rwxr-xr-x  tarek/staff      65 2008-06-09 13:26:54 ./config
-rwx----- tarek/staff     668 2008-06-09 13:26:54 ./id_dsa
-rwxr-xr-x  tarek/staff     609 2008-06-09 13:26:54 ./id_dsa.pub
-rw-----  tarek/staff    1675 2008-06-09 13:26:54 ./id_rsa
-rw-r--r--  tarek/staff     397 2008-06-09 13:26:54 ./id_rsa.pub
-rw-r--r--  tarek/staff   37192 2010-02-06 18:23:10 ./known_hosts
```

## 10.11 dircache — Cached directory listings

Deprecated since version 2.6: The `dircache` module has been removed in Python 3. The `dircache` module defines a function for reading directory listing using a cache, and cache invalidation using the *mtime* of the directory. Additionally, it defines a function to annotate directories by appending a slash.

The `dircache` module defines the following functions:

`dircache.reset()`

Resets the directory cache.

`dircache.listdir(path)`

Return a directory listing of *path*, as gotten from `os.listdir()`. Note that unless *path* changes, further call to `.listdir()` will not re-read the directory structure.

Note that the list returned should be regarded as read-only. (Perhaps a future version should change it to return a tuple?)

`dircache.opendir(path)`

Same as `.listdir()`. Defined for backwards compatibility.

`dircache.annotate(head, list)`

Assume *list* is a list of paths relative to *head*, and append, in place, a `'/'` to each path which points to a directory.

```
>>> import dircache
>>> a = dircache.listdir('/')
>>> a = a[:] # Copy the return value so we can change 'a'
```

```
>>> a
['bin', 'boot', 'cdrom', 'dev', 'etc', 'floppy', 'home', 'initrd', 'lib', 'lost+
found', 'mnt', 'proc', 'root', 'sbin', 'tmp', 'usr', 'var', 'vmlinuz']
>>> dircache.annotate('/', a)
>>> a
['bin/', 'boot/', 'cdrom/', 'dev/', 'etc/', 'floppy/', 'home/', 'initrd/', 'lib/
', 'lost+found/', 'mnt/', 'proc/', 'root/', 'sbin/', 'tmp/', 'usr/', 'var/', 'vm
linuz']
```

## 10.12 `macpath` — Mac OS 9 path manipulation functions

This module is the Mac OS 9 (and earlier) implementation of the `os.path` module. It can be used to manipulate old-style Macintosh pathnames on Mac OS X (or any other platform).

The following functions are available in this module: `normcase()`, `normpath()`, `isabs()`, `join()`, `split()`, `isdir()`, `isfile()`, `walk()`, `exists()`. For other functions available in `os.path` dummy counterparts are available.

### See Also:

**Section *File Objects*** A description of Python's built-in file objects.

**Module `os`** Operating system interfaces, including functions to work with files at a lower level than the built-in file object.



# DATA PERSISTENCE

The modules described in this chapter support storing Python data in a persistent form on disk. The `pickle` and `marshal` modules can turn many Python data types into a stream of bytes and then recreate the objects from the bytes. The various DBM-related modules support a family of hash-based file formats that store a mapping of strings to other strings. The `bsddb` module also provides such disk-based string-to-string mappings based on hashing, and also supports B-Tree and record-based formats.

The list of modules described in this chapter is:

## 11.1 `pickle` — Python object serialization

The `pickle` module implements a fundamental, but powerful algorithm for serializing and de-serializing a Python object structure. “Pickling” is the process whereby a Python object hierarchy is converted into a byte stream, and “unpickling” is the inverse operation, whereby a byte stream is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as “serialization”, “marshalling,”<sup>1</sup> or “flattening”, however, to avoid confusion, the terms used here are “pickling” and “unpickling”.

This documentation describes both the `pickle` module and the `cPickle` module.

**Warning:** The `pickle` module is not intended to be secure against erroneous or maliciously constructed data. Never unpickle data received from an untrusted or unauthenticated source.

### 11.1.1 Relationship to other Python modules

The `pickle` module has an optimized cousin called the `cPickle` module. As its name implies, `cPickle` is written in C, so it can be up to 1000 times faster than `pickle`. However it does not support subclassing of the `Pickler()` and `Unpickler()` classes, because in `cPickle` these are functions, not classes. Most applications have no need for this functionality, and can benefit from the improved performance of `cPickle`. Other than that, the interfaces of the two modules are nearly identical; the common interface is described in this manual and differences are pointed out where necessary. In the following discussions, we use the term “pickle” to collectively describe the `pickle` and `cPickle` modules.

The data streams the two modules produce are guaranteed to be interchangeable.

Python has a more primitive serialization module called `marshal`, but in general `pickle` should always be the preferred way to serialize Python objects. `marshal` exists primarily to support Python’s `.pyc` files.

The `pickle` module differs from `marshal` in several significant ways:

---

<sup>1</sup> Don’t confuse this with the `marshal` module

- The `pickle` module keeps track of the objects it has already serialized, so that later references to the same object won't be serialized again. `marshal` doesn't do this.

This has implications both for recursive objects and object sharing. Recursive objects are objects that contain references to themselves. These are not handled by `marshal`, and in fact, attempting to marshal recursive objects will crash your Python interpreter. Object sharing happens when there are multiple references to the same object in different places in the object hierarchy being serialized. `pickle` stores such objects only once, and ensures that all other references point to the master copy. Shared objects remain shared, which can be very important for mutable objects.

- `marshal` cannot be used to serialize user-defined classes and their instances. `pickle` can save and restore class instances transparently, however the class definition must be importable and live in the same module as when the object was stored.
- The `marshal` serialization format is not guaranteed to be portable across Python versions. Because its primary job in life is to support `.pyc` files, the Python implementers reserve the right to change the serialization format in non-backwards compatible ways should the need arise. The `pickle` serialization format is guaranteed to be backwards compatible across Python releases.

Note that serialization is a more primitive notion than persistence; although `pickle` reads and writes file objects, it does not handle the issue of naming persistent objects, nor the (even more complicated) issue of concurrent access to persistent objects. The `pickle` module can transform a complex object into a byte stream and it can transform the byte stream into an object with the same internal structure. Perhaps the most obvious thing to do with these byte streams is to write them onto a file, but it is also conceivable to send them across a network or store them in a database. The module `shelve` provides a simple interface to pickle and unpickle objects on DBM-style database files.

### 11.1.2 Data stream format

The data format used by `pickle` is Python-specific. This has the advantage that there are no restrictions imposed by external standards such as XDR (which can't represent pointer sharing); however it means that non-Python programs may not be able to reconstruct pickled Python objects.

By default, the `pickle` data format uses a printable ASCII representation. This is slightly more voluminous than a binary representation. The big advantage of using printable ASCII (and of some other characteristics of `pickle`'s representation) is that for debugging or recovery purposes it is possible for a human to read the pickled file with a standard text editor.

There are currently 3 different protocols which can be used for pickling.

- Protocol version 0 is the original ASCII protocol and is backwards compatible with earlier versions of Python.
- Protocol version 1 is the old binary format which is also compatible with earlier versions of Python.
- Protocol version 2 was introduced in Python 2.3. It provides much more efficient pickling of *new-style classes*.

Refer to **PEP 307** for more information.

If a *protocol* is not specified, protocol 0 is used. If *protocol* is specified as a negative value or `HIGHEST_PROTOCOL`, the highest protocol version available will be used. Changed in version 2.3: Introduced the *protocol* parameter. A binary format, which is slightly more efficient, can be chosen by specifying a *protocol* version  $\geq 1$ .

### 11.1.3 Usage

To serialize an object hierarchy, you first create a pickler, then you call the pickler's `dump()` method. To de-serialize a data stream, you first create an unpickler, then you call the unpickler's `load()` method. The `pickle` module provides the following constant:

`pickle.HIGHEST_PROTOCOL`

The highest protocol version available. This value can be passed as a *protocol* value. New in version 2.3.

**Note:** Be sure to always open pickle files created with protocols  $\geq 1$  in binary mode. For the old ASCII-based pickle protocol 0 you can use either text mode or binary mode as long as you stay consistent.

A pickle file written with protocol 0 in binary mode will contain lone linefeeds as line terminators and therefore will look “funny” when viewed in Notepad or other editors which do not support this format.

The `pickle` module provides the following functions to make the pickling process more convenient:

`pickle.dump(obj, file[, protocol])`

Write a pickled representation of *obj* to the open file object *file*. This is equivalent to `Pickler(file, protocol).dump(obj)`.

If the *protocol* parameter is omitted, protocol 0 is used. If *protocol* is specified as a negative value or `HIGHEST_PROTOCOL`, the highest protocol version will be used. Changed in version 2.3: Introduced the *protocol* parameter. *file* must have a `write()` method that accepts a single string argument. It can thus be a file object opened for writing, a `StringIO` object, or any other custom object that meets this interface.

`pickle.load(file)`

Read a string from the open file object *file* and interpret it as a pickle data stream, reconstructing and returning the original object hierarchy. This is equivalent to `Unpickler(file).load()`.

*file* must have two methods, a `read()` method that takes an integer argument, and a `readline()` method that requires no arguments. Both methods should return a string. Thus *file* can be a file object opened for reading, a `StringIO` object, or any other custom object that meets this interface.

This function automatically determines whether the data stream was written in binary mode or not.

`pickle.dumps(obj[, protocol])`

Return the pickled representation of the object as a string, instead of writing it to a file.

If the *protocol* parameter is omitted, protocol 0 is used. If *protocol* is specified as a negative value or `HIGHEST_PROTOCOL`, the highest protocol version will be used. Changed in version 2.3: The *protocol* parameter was added.

`pickle.loads(string)`

Read a pickled object hierarchy from a string. Characters in the string past the pickled object’s representation are ignored.

The `pickle` module also defines three exceptions:

**exception** `pickle.PickleError`

A common base class for the other exceptions defined below. This inherits from `Exception`.

**exception** `pickle.PicklingError`

This exception is raised when an unpicklable object is passed to the `dump()` method.

**exception** `pickle.UnpicklingError`

This exception is raised when there is a problem unpickling an object. Note that other exceptions may also be raised during unpickling, including (but not necessarily limited to) `AttributeError`, `EOFError`, `ImportError`, and `IndexError`.

The `pickle` module also exports two callables<sup>2</sup>, `Pickler` and `Unpickler`:

**class** `pickle.Pickler(file[, protocol])`

This takes a file-like object to which it will write a pickle data stream.

<sup>2</sup> In the `pickle` module these callables are classes, which you could subclass to customize the behavior. However, in the `cPickle` module these callables are factory functions and so cannot be subclassed. One common reason to subclass is to control what objects can actually be unpickled. See section *Subclassing Unpicklers* for more details.

If the *protocol* parameter is omitted, protocol 0 is used. If *protocol* is specified as a negative value or `HIGHEST_PROTOCOL`, the highest protocol version will be used. Changed in version 2.3: Introduced the *protocol* parameter. *file* must have a `write()` method that accepts a single string argument. It can thus be an open file object, a `StringIO` object, or any other custom object that meets this interface.

`Pickler` objects define one (or two) public methods:

**dump** (*obj*)

Write a pickled representation of *obj* to the open file object given in the constructor. Either the binary or ASCII format will be used, depending on the value of the *protocol* argument passed to the constructor.

**clear\_memo** ()

Clears the pickler's "memo". The memo is the data structure that remembers which objects the pickler has already seen, so that shared or recursive objects pickled by reference and not by value. This method is useful when re-using picklers.

---

**Note:** Prior to Python 2.3, `clear_memo()` was only available on the picklers created by `cPickle`. In the `pickle` module, picklers have an instance variable called `memo` which is a Python dictionary. So to clear the memo for a `pickle` module pickler, you could do the following:

```
mypickler.memo.clear()
```

Code that does not need to support older versions of Python should simply use `clear_memo()`.

---

It is possible to make multiple calls to the `dump()` method of the same `Pickler` instance. These must then be matched to the same number of calls to the `load()` method of the corresponding `Unpickler` instance. If the same object is pickled by multiple `dump()` calls, the `load()` will all yield references to the same object.<sup>3</sup>

`Unpickler` objects are defined as:

**class** `pickle.Unpickler` (*file*)

This takes a file-like object from which it will read a pickle data stream. This class automatically determines whether the data stream was written in binary mode or not, so it does not need a flag as in the `Pickler` factory.

*file* must have two methods, a `read()` method that takes an integer argument, and a `readline()` method that requires no arguments. Both methods should return a string. Thus *file* can be a file object opened for reading, a `StringIO` object, or any other custom object that meets this interface.

`Unpickler` objects have one (or two) public methods:

**load** ()

Read a pickled object representation from the open file object given in the constructor, and return the reconstituted object hierarchy specified therein.

This method automatically determines whether the data stream was written in binary mode or not.

**noload** ()

This is just like `load()` except that it doesn't actually create any objects. This is useful primarily for finding what's called "persistent ids" that may be referenced in a pickle data stream. See section *The pickle protocol* below for more details.

**Note:** the `noload()` method is currently only available on `Unpickler` objects created with the `cPickle` module. `pickle` module `Unpicklers` do not have the `noload()` method.

---

<sup>3</sup> *Warning:* this is intended for pickling multiple objects without intervening modifications to the objects or their parts. If you modify an object and then pickle it again using the same `Pickler` instance, the object is not pickled again — a reference to it is pickled and the `Unpickler` will return the old value, not the modified one. There are two problems here: (1) detecting changes, and (2) marshalling a minimal set of changes. Garbage Collection may also become a problem here.

### 11.1.4 What can be pickled and unpickled?

The following types can be pickled:

- `None`, `True`, and `False`
- integers, long integers, floating point numbers, complex numbers
- normal and Unicode strings
- tuples, lists, sets, and dictionaries containing only picklable objects
- functions defined at the top level of a module
- built-in functions defined at the top level of a module
- classes that are defined at the top level of a module
- instances of such classes whose `__dict__` or `__setstate__()` is picklable (see section *The pickle protocol* for details)

Attempts to pickle unpicklable objects will raise the `PicklingError` exception; when this happens, an unspecified number of bytes may have already been written to the underlying file. Trying to pickle a highly recursive data structure may exceed the maximum recursion depth, a `RuntimeError` will be raised in this case. You can carefully raise this limit with `sys.setrecursionlimit()`.

Note that functions (built-in and user-defined) are pickled by “fully qualified” name reference, not by value. This means that only the function name is pickled, along with the name of the module the function is defined in. Neither the function’s code, nor any of its function attributes are pickled. Thus the defining module must be importable in the unpickling environment, and the module must contain the named object, otherwise an exception will be raised.<sup>4</sup>

Similarly, classes are pickled by named reference, so the same restrictions in the unpickling environment apply. Note that none of the class’s code or data is pickled, so in the following example the class attribute `attr` is not restored in the unpickling environment:

```
class Foo:
    attr = 'a class attr'

picklestring = pickle.dumps(Foo)
```

These restrictions are why picklable functions and classes must be defined in the top level of a module.

Similarly, when class instances are pickled, their class’s code and data are not pickled along with them. Only the instance data are pickled. This is done on purpose, so you can fix bugs in a class or add methods to the class and still load objects that were created with an earlier version of the class. If you plan to have long-lived objects that will see many versions of a class, it may be worthwhile to put a version number in the objects so that suitable conversions can be made by the class’s `__setstate__()` method.

### 11.1.5 The pickle protocol

This section describes the “pickling protocol” that defines the interface between the pickler/unpickler and the objects that are being serialized. This protocol provides a standard way for you to define, customize, and control how your objects are serialized and de-serialized. The description in this section doesn’t cover specific customizations that you can employ to make the unpickling environment slightly safer from untrusted pickle data streams; see section *Subclassing Unpicklers* for more details.

<sup>4</sup> The exception raised will likely be an `ImportError` or an `AttributeError` but it could be something else.

## Pickling and unpickling normal class instances

object.**\_\_getinitargs\_\_**()

When a pickled class instance is unpickled, its `__init__()` method is normally *not* invoked. If it is desirable that the `__init__()` method be called on unpickling, an old-style class can define a method `__getinitargs__()`, which should return a *tuple* containing the arguments to be passed to the class constructor (`__init__()` for example). The `__getinitargs__()` method is called at pickle time; the tuple it returns is incorporated in the pickle for the instance.

object.**\_\_getnewargs\_\_**()

New-style types can provide a `__getnewargs__()` method that is used for protocol 2. Implementing this method is needed if the type establishes some internal invariants when the instance is created, or if the memory allocation is affected by the values passed to the `__new__()` method for the type (as it is for tuples and strings). Instances of a *new-style class* `C` are created using

```
obj = C.__new__(C, *args)
```

where `args` is the result of calling `__getnewargs__()` on the original object; if there is no `__getnewargs__()`, an empty tuple is assumed.

object.**\_\_getstate\_\_**()

Classes can further influence how their instances are pickled; if the class defines the method `__getstate__()`, it is called and the return state is pickled as the contents for the instance, instead of the contents of the instance's dictionary. If there is no `__getstate__()` method, the instance's `__dict__` is pickled.

object.**\_\_setstate\_\_**(state)

Upon unpickling, if the class also defines the method `__setstate__()`, it is called with the unpickled state.<sup>5</sup> If there is no `__setstate__()` method, the pickled state must be a dictionary and its items are assigned to the new instance's dictionary. If a class defines both `__getstate__()` and `__setstate__()`, the state object needn't be a dictionary and these methods can do what they want.<sup>6</sup>

---

**Note:** For *new-style classes*, if `__getstate__()` returns a false value, the `__setstate__()` method will not be called.

---

---

**Note:** At unpickling time, some methods like `__getattr__()`, `__getattribute__()`, or `__setattr__()` may be called upon the instance. In case those methods rely on some internal invariant being true, the type should implement either `__getinitargs__()` or `__getnewargs__()` to establish such an invariant; otherwise, neither `__new__()` nor `__init__()` will be called.

---

## Pickling and unpickling extension types

object.**\_\_reduce\_\_**()

When the `Pickler` encounters an object of a type it knows nothing about — such as an extension type — it looks in two places for a hint of how to pickle it. One alternative is for the object to implement a `__reduce__()` method. If provided, at pickling time `__reduce__()` will be called with no arguments, and it must return either a string or a tuple.

If a string is returned, it names a global variable whose contents are pickled as normal. The string returned by `__reduce__()` should be the object's local name relative to its module; the pickle module searches the module namespace to determine the object's module.

---

<sup>5</sup> These methods can also be used to implement copying class instances.

<sup>6</sup> This protocol is also used by the shallow and deep copying operations defined in the `copy` module.

When a tuple is returned, it must be between two and five elements long. Optional elements can either be omitted, or `None` can be provided as their value. The contents of this tuple are pickled as normal and used to reconstruct the object at unpickling time. The semantics of each element are:

- A callable object that will be called to create the initial version of the object. The next element of the tuple will provide arguments for this callable, and later elements provide additional state information that will subsequently be used to fully reconstruct the pickled data.

In the unpickling environment this object must be either a class, a callable registered as a “safe constructor” (see below), or it must have an attribute `__safe_for_unpickling__` with a true value. Otherwise, an `UnpicklingError` will be raised in the unpickling environment. Note that as usual, the callable itself is pickled by name.

- A tuple of arguments for the callable object. Changed in version 2.5: Formerly, this argument could also be `None`.
- Optionally, the object’s state, which will be passed to the object’s `__setstate__()` method as described in section *Pickling and unpickling normal class instances*. If the object has no `__setstate__()` method, then, as above, the value must be a dictionary and it will be added to the object’s `__dict__`.
- Optionally, an iterator (and not a sequence) yielding successive list items. These list items will be pickled, and appended to the object using either `obj.append(item)` or `obj.extend(list_of_items)`. This is primarily used for list subclasses, but may be used by other classes as long as they have `append()` and `extend()` methods with the appropriate signature. (Whether `append()` or `extend()` is used depends on which pickle protocol version is used as well as the number of items to append, so both must be supported.)
- Optionally, an iterator (not a sequence) yielding successive dictionary items, which should be tuples of the form `(key, value)`. These items will be pickled and stored to the object using `obj[key] = value`. This is primarily used for dictionary subclasses, but may be used by other classes as long as they implement `__setitem__()`.

`object.__reduce_ex__` (*protocol*)

It is sometimes useful to know the protocol version when implementing `__reduce__()`. This can be done by implementing a method named `__reduce_ex__()` instead of `__reduce__()`. `__reduce_ex__()`, when it exists, is called in preference over `__reduce__()` (you may still provide `__reduce__()` for backwards compatibility). The `__reduce_ex__()` method will be called with a single integer argument, the protocol version.

The `object` class implements both `__reduce__()` and `__reduce_ex__()`; however, if a subclass overrides `__reduce__()` but not `__reduce_ex__()`, the `__reduce_ex__()` implementation detects this and calls `__reduce__()`.

An alternative to implementing a `__reduce__()` method on the object to be pickled, is to register the callable with the `copy_reg` module. This module provides a way for programs to register “reduction functions” and constructors for user-defined types. Reduction functions have the same semantics and interface as the `__reduce__()` method described above, except that they are called with a single argument, the object to be pickled.

The registered constructor is deemed a “safe constructor” for purposes of unpickling as described above.

## Pickling and unpickling external objects

For the benefit of object persistence, the `pickle` module supports the notion of a reference to an object outside the pickled data stream. Such objects are referenced by a “persistent id”, which is just an arbitrary string of printable ASCII characters. The resolution of such names is not defined by the `pickle` module; it will delegate this resolution to user defined functions on the pickler and unpickler.<sup>7</sup>

<sup>7</sup> The actual mechanism for associating these user defined functions is slightly different for `pickle` and `cPickle`. The description given here works the same for both implementations. Users of the `pickle` module could also use subclassing to effect the same results, overriding the

To define external persistent id resolution, you need to set the `persistent_id` attribute of the pickler object and the `persistent_load` attribute of the unpickler object.

To pickle objects that have an external persistent id, the pickler must have a custom `persistent_id()` method that takes an object as an argument and returns either `None` or the persistent id for that object. When `None` is returned, the pickler simply pickles the object as normal. When a persistent id string is returned, the pickler will pickle that string, along with a marker so that the unpickler will recognize the string as a persistent id.

To unpickle external objects, the unpickler must have a custom `persistent_load()` function that takes a persistent id string and returns the referenced object.

Here's a silly example that *might* shed more light:

```
import pickle
from cStringIO import StringIO

src = StringIO()
p = pickle.Pickler(src)

def persistent_id(obj):
    if hasattr(obj, 'x'):
        return 'the value %d' % obj.x
    else:
        return None

p.persistent_id = persistent_id

class Integer:
    def __init__(self, x):
        self.x = x
    def __str__(self):
        return 'My name is integer %d' % self.x

i = Integer(7)
print i
p.dump(i)

datastream = src.getvalue()
print repr(datastream)
dst = StringIO(datastream)

up = pickle.Unpickler(dst)

class FancyInteger(Integer):
    def __str__(self):
        return 'I am the integer %d' % self.x

def persistent_load(persid):
    if persid.startswith('the value '):
        value = int(persid.split()[2])
        return FancyInteger(value)
    else:
        raise pickle.UnpicklingError, 'Invalid persistent id'
```

---

`persistent_id()` and `persistent_load()` methods in the derived classes.

```
up.persistent_load = persistent_load

j = up.load()
print j
```

In the `cPickle` module, the unpickler’s `persistent_load` attribute can also be set to a Python list, in which case, when the unpickler reaches a persistent id, the persistent id string will simply be appended to this list. This functionality exists so that a pickle data stream can be “sniffed” for object references without actually instantiating all the objects in a pickle.<sup>8</sup> Setting `persistent_load` to a list is usually used in conjunction with the `noload()` method on the Unpickler.

### 11.1.6 Subclassing Unpicklers

By default, unpickling will import any class that it finds in the pickle data. You can control exactly what gets unpickled and what gets called by customizing your unpickler. Unfortunately, exactly how you do this is different depending on whether you’re using `pickle` or `cPickle`.<sup>9</sup>

In the `pickle` module, you need to derive a subclass from `Unpickler`, overriding the `load_global()` method. `load_global()` should read two lines from the pickle data stream where the first line will be the name of the module containing the class and the second line will be the name of the instance’s class. It then looks up the class, possibly importing the module and digging out the attribute, then it appends what it finds to the unpickler’s stack. Later on, this class will be assigned to the `__class__` attribute of an empty class, as a way of magically creating an instance without calling its class’s `__init__()`. Your job (should you choose to accept it), would be to have `load_global()` push onto the unpickler’s stack, a known safe version of any class you deem safe to unpickle. It is up to you to produce such a class. Or you could raise an error if you want to disallow all unpickling of instances. If this sounds like a hack, you’re right. Refer to the source code to make this work.

Things are a little cleaner with `cPickle`, but not by much. To control what gets unpickled, you can set the unpickler’s `find_global` attribute to a function or `None`. If it is `None` then any attempts to unpickle instances will raise an `UnpicklingError`. If it is a function, then it should accept a module name and a class name, and return the corresponding class object. It is responsible for looking up the class and performing any necessary imports, and it may raise an error to prevent instances of the class from being unpickled.

The moral of the story is that you should be really careful about the source of the strings your application unpickles.

### 11.1.7 Example

For the simplest code, use the `dump()` and `load()` functions. Note that a self-referencing list is pickled and restored correctly.

```
import pickle

data1 = {'a': [1, 2.0, 3, 4+6j],
        'b': ('string', u'Unicode string'),
        'c': None}

selfref_list = [1, 2, 3]
selfref_list.append(selfref_list)

output = open('data.pkl', 'wb')

# Pickle dictionary using protocol 0.
```

<sup>8</sup> We’ll leave you with the image of Guido and Jim sitting around sniffing pickles in their living rooms.

<sup>9</sup> A word of caution: the mechanisms described here use internal attributes and methods, which are subject to change in future versions of Python. We intend to someday provide a common interface for controlling this behavior, which will work in either `pickle` or `cPickle`.

```
pickle.dump(data1, output)

# Pickle the list using the highest protocol available.
pickle.dump(selfref_list, output, -1)

output.close()
```

The following example reads the resulting pickled data. When reading a pickle-containing file, you should open the file in binary mode because you can't be sure if the ASCII or binary format was used.

```
import pprint, pickle

pkl_file = open('data.pkl', 'rb')

data1 = pickle.load(pkl_file)
pprint.pprint(data1)

data2 = pickle.load(pkl_file)
pprint.pprint(data2)

pkl_file.close()
```

Here's a larger example that shows how to modify pickling behavior for a class. The `TextReader` class opens a text file, and returns the line number and line contents each time its `readline()` method is called. If a `TextReader` instance is pickled, all attributes *except* the file object member are saved. When the instance is unpickled, the file is reopened, and reading resumes from the last location. The `__setstate__()` and `__getstate__()` methods are used to implement this behavior.

```
#!/usr/local/bin/python

class TextReader:
    """Print and number lines in a text file."""
    def __init__(self, file):
        self.file = file
        self.fh = open(file)
        self.lineno = 0

    def readline(self):
        self.lineno = self.lineno + 1
        line = self.fh.readline()
        if not line:
            return None
        if line.endswith("\n"):
            line = line[:-1]
        return "%d: %s" % (self.lineno, line)

    def __getstate__(self):
        odict = self.__dict__.copy() # copy the dict since we change it
        del odict['fh'] # remove filehandle entry
        return odict

    def __setstate__(self, dict):
        fh = open(dict['file']) # reopen file
        count = dict['lineno'] # read from file...
        while count: # until line count is restored
            fh.readline()
```

```

        count = count - 1
    self.__dict__.update(dict)    # update attributes
    self.fh = fh                 # save the file object

```

A sample usage might be something like this:

```

>>> import TextReader
>>> obj = TextReader.TextReader("TextReader.py")
>>> obj.readline()
'1: #!/usr/local/bin/python'
>>> obj.readline()
'2: '
>>> obj.readline()
'3: class TextReader:'
>>> import pickle
>>> pickle.dump(obj, open('save.p', 'wb'))

```

If you want to see that `pickle` works across Python processes, start another Python session, before continuing. What follows can happen from either the same process or a new process.

```

>>> import pickle
>>> reader = pickle.load(open('save.p', 'rb'))
>>> reader.readline()
'4:     """Print and number lines in a text file."""'

```

**See Also:**

**Module `copy_reg`** Pickle interface constructor registration for extension types.

**Module `shelve`** Indexed databases of objects; uses `pickle`.

**Module `copy`** Shallow and deep object copying.

**Module `marshal`** High-performance serialization of built-in types.

## 11.2 cPickle — A faster pickle

The `cPickle` module supports serialization and de-serialization of Python objects, providing an interface and functionality nearly identical to the `pickle` module. There are several differences, the most important being performance and subclassability.

First, `cPickle` can be up to 1000 times faster than `pickle` because the former is implemented in C. Second, in the `cPickle` module the callables `Pickler()` and `Unpickler()` are functions, not classes. This means that you cannot use them to derive custom pickling and unpickling subclasses. Most applications have no need for this functionality and should benefit from the greatly improved performance of the `cPickle` module.

The pickle data stream produced by `pickle` and `cPickle` are identical, so it is possible to use `pickle` and `cPickle` interchangeably with existing pickles.<sup>10</sup>

There are additional minor differences in API between `cPickle` and `pickle`, however for most applications, they are interchangeable. More documentation is provided in the `pickle` module documentation, which includes a list of the documented differences.

<sup>10</sup> Since the pickle data format is actually a tiny stack-oriented programming language, and some freedom is taken in the encodings of certain objects, it is possible that the two modules produce different data streams for the same input objects. However it is guaranteed that they will always be able to read each other's data streams.

## 11.3 `copy_reg` — Register `pickle` support functions

---

**Note:** The `copy_reg` module has been renamed to `copyreg` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

The `copy_reg` module provides support for the `pickle` and `cPickle` modules. The `copy` module is likely to use this in the future as well. It provides configuration information about object constructors which are not classes. Such constructors may be factory functions or class instances.

`copy_reg.constructor` (*object*)

Declares *object* to be a valid constructor. If *object* is not callable (and hence not valid as a constructor), raises `TypeError`.

`copy_reg.pickle` (*type*, *function*[, *constructor* ])

Declares that *function* should be used as a “reduction” function for objects of type *type*; *type* must not be a “classic” class object. (Classic classes are handled differently; see the documentation for the `pickle` module for details.) *function* should return either a string or a tuple containing two or three elements.

The optional *constructor* parameter, if provided, is a callable object which can be used to reconstruct the object when called with the tuple of arguments returned by *function* at pickling time. `TypeError` will be raised if *object* is a class or *constructor* is not callable.

See the `pickle` module for more details on the interface expected of *function* and *constructor*.

## 11.4 `shelve` — Python object persistence

**Source code:** `Lib/shelve.py`

---

A “shelf” is a persistent, dictionary-like object. The difference with “dbm” databases is that the values (not the keys!) in a shelf can be essentially arbitrary Python objects — anything that the `pickle` module can handle. This includes most class instances, recursive data types, and objects containing lots of shared sub-objects. The keys are ordinary strings.

`shelve.open` (*filename*, *flag*='c', *protocol*=None, *writeback*=False)

Open a persistent dictionary. The filename specified is the base filename for the underlying database. As a side-effect, an extension may be added to the filename and more than one file may be created. By default, the underlying database file is opened for reading and writing. The optional *flag* parameter has the same interpretation as the *flag* parameter of `anydbm.open()`.

By default, version 0 pickles are used to serialize values. The version of the pickle protocol can be specified with the *protocol* parameter. Changed in version 2.3: The *protocol* parameter was added. Because of Python semantics, a shelf cannot know when a mutable persistent-dictionary entry is modified. By default modified objects are written *only* when assigned to the shelf (see *Example*). If the optional *writeback* parameter is set to `True`, all entries accessed are also cached in memory, and written back on `sync()` and `close()`; this can make it handier to mutate mutable entries in the persistent dictionary, but, if many entries are accessed, it can consume vast amounts of memory for the cache, and it can make the close operation very slow since all accessed entries are written back (there is no way to determine which accessed entries are mutable, nor which ones were actually mutated).

Like file objects, shelve objects should be closed explicitly to ensure that the persistent data is flushed to disk.

Since the `shelve` module stores objects using `pickle`, the same security precautions apply. Accordingly, you should avoid loading a shelf from an untrusted source.

Shelf objects support all methods supported by dictionaries. This eases the transition from dictionary based scripts to those requiring persistent storage.

Two additional methods are supported:

`Shelf.sync()`

Write back all entries in the cache if the shelf was opened with `writeback` set to `True`. Also empty the cache and synchronize the persistent dictionary on disk, if feasible. This is called automatically when the shelf is closed with `close()`.

`Shelf.close()`

Synchronize and close the persistent `dict` object. Operations on a closed shelf will fail with a `ValueError`.

**See Also:**

[Persistent dictionary recipe](#) with widely supported storage formats and having the speed of native dictionaries.

### 11.4.1 Restrictions

- The choice of which database package will be used (such as `dbm`, `gdbm` or `bsddb`) depends on which interface is available. Therefore it is not safe to open the database directly using `dbm`. The database is also (unfortunately) subject to the limitations of `dbm`, if it is used — this means that (the pickled representation of) the objects stored in the database should be fairly small, and in rare cases key collisions may cause the database to refuse updates.
- The `shelve` module does not support *concurrent* read/write access to shelved objects. (Multiple simultaneous read accesses are safe.) When a program has a shelf open for writing, no other program should have it open for reading or writing. Unix file locking can be used to solve this, but this differs across Unix versions and requires knowledge about the database implementation used.

**class** `shelve.Shelf` (*dict*, *protocol=None*, *writeback=False*)

A subclass of `UserDict.DictMixin` which stores pickled values in the `dict` object.

By default, version 0 pickles are used to serialize values. The version of the pickle protocol can be specified with the `protocol` parameter. See the `pickle` documentation for a discussion of the pickle protocols. Changed in version 2.3: The `protocol` parameter was added. If the `writeback` parameter is `True`, the object will hold a cache of all entries accessed and write them back to the `dict` at sync and close times. This allows natural operations on mutable entries, but can consume much more memory and make sync and close take a long time.

**class** `shelve.BsddbShelf` (*dict*, *protocol=None*, *writeback=False*)

A subclass of `Shelf` which exposes `first()`, `next()`, `previous()`, `last()` and `set_location()` which are available in the `bsddb` module but not in other database modules. The `dict` object passed to the constructor must support those methods. This is generally accomplished by calling one of `bsddb.hashopen()`, `bsddb.btopen()` or `bsddb.rnopen()`. The optional `protocol` and `writeback` parameters have the same interpretation as for the `Shelf` class.

**class** `shelve.DbfilenameShelf` (*filename*, *flag='c'*, *protocol=None*, *writeback=False*)

A subclass of `Shelf` which accepts a `filename` instead of a dict-like object. The underlying file will be opened using `anydbm.open()`. By default, the file will be created and opened for both read and write. The optional `flag` parameter has the same interpretation as for the `open()` function. The optional `protocol` and `writeback` parameters have the same interpretation as for the `Shelf` class.

### 11.4.2 Example

To summarize the interface (key is a string, data is an arbitrary object):

**import shelve**

```
d = shelve.open(filename) # open -- file may get suffix added by low-level
                          # library

d[key] = data             # store data at key (overwrites old data if
                          # using an existing key)
data = d[key]             # retrieve a COPY of data at key (raise KeyError if no
                          # such key)
del d[key]                # delete data stored at key (raises KeyError
                          # if no such key)
flag = d.has_key(key)     # true if the key exists
klist = d.keys()          # a list of all existing keys (slow!)

# as d was opened WITHOUT writeback=True, beware:
d['xx'] = range(4)        # this works as expected, but...
d['xx'].append(5)         # *this doesn't!* -- d['xx'] is STILL range(4)!

# having opened d without writeback=True, you need to code carefully:
temp = d['xx']             # extracts the copy
temp.append(5)             # mutates the copy
d['xx'] = temp             # stores the copy right back, to persist it

# or, d=shelve.open(filename,writeback=True) would let you just code
# d['xx'].append(5) and have it work as expected, BUT it would also
# consume more memory and make the d.close() operation slower.

d.close()                 # close it
```

**See Also:**

**Module `anydbm`** Generic interface to dbm-style databases.

**Module `bsddb`** BSD db database interface.

**Module `dbhash`** Thin layer around the `bsddb` which provides an `open()` function like the other database modules.

**Module `dbm`** Standard Unix database interface.

**Module `dumbdbm`** Portable implementation of the dbm interface.

**Module `gdbm`** GNU database interface, based on the dbm interface.

**Module `pickle`** Object serialization used by `shelve`.

**Module `cPickle`** High-performance version of `pickle`.

## 11.5 `marshal` — Internal Python object serialization

This module contains functions that can read and write Python values in a binary format. The format is specific to Python, but independent of machine architecture issues (e.g., you can write a Python value to a file on a PC, transport the file to a Sun, and read it back there). Details of the format are undocumented on purpose; it may change between Python versions (although it rarely does).<sup>11</sup>

---

<sup>11</sup> The name of this module stems from a bit of terminology used by the designers of Modula-3 (amongst others), who use the term “marshalling” for shipping of data around in a self-contained form. Strictly speaking, “to marshal” means to convert some data from internal to external form (in an RPC buffer for instance) and “unmarshalling” for the reverse process.

This is not a general “persistence” module. For general persistence and transfer of Python objects through RPC calls, see the modules `pickle` and `shelve`. The `marshal` module exists mainly to support reading and writing the “pseudo-compiled” code for Python modules of `.pyc` files. Therefore, the Python maintainers reserve the right to modify the marshal format in backward incompatible ways should the need arise. If you’re serializing and deserializing Python objects, use the `pickle` module instead – the performance is comparable, version independence is guaranteed, and pickle supports a substantially wider range of objects than marshal.

**Warning:** The `marshal` module is not intended to be secure against erroneous or maliciously constructed data. Never unmarshal data received from an untrusted or unauthenticated source.

Not all Python object types are supported; in general, only objects whose value is independent from a particular invocation of Python can be written and read by this module. The following types are supported: booleans, integers, long integers, floating point numbers, complex numbers, strings, Unicode objects, tuples, lists, sets, frozensets, dictionaries, and code objects, where it should be understood that tuples, lists, sets, frozensets and dictionaries are only supported as long as the values contained therein are themselves supported; and recursive lists, sets and dictionaries should not be written (they will cause infinite loops). The singletons `None`, `Ellipsis` and `StopIteration` can also be marshalled and unmarshalled.

**Warning:** On machines where C’s `long int` type has more than 32 bits (such as the DEC Alpha), it is possible to create plain Python integers that are longer than 32 bits. If such an integer is marshaled and read back in on a machine where C’s `long int` type has only 32 bits, a Python long integer object is returned instead. While of a different type, the numeric value is the same. (This behavior is new in Python 2.2. In earlier versions, all but the least-significant 32 bits of the value were lost, and a warning message was printed.)

There are functions that read/write files as well as functions operating on strings.

The module defines these functions:

`marshal.dump` (*value*, *file* [, *version* ])

Write the value on the open file. The value must be a supported type. The file must be an open file object such as `sys.stdout` or returned by `open()` or `os.popen()`. It must be opened in binary mode (`'wb'` or `'w+b'`).

If the value has (or contains an object that has) an unsupported type, a `ValueError` exception is raised — but garbage data will also be written to the file. The object will not be properly read back by `load()`. New in version 2.4: The *version* argument indicates the data format that `dump` should use (see below).

`marshal.load` (*file*)

Read one value from the open file and return it. If no valid value is read (e.g. because the data has a different Python version’s incompatible marshal format), raise `EOFError`, `ValueError` or `TypeError`. The file must be an open file object opened in binary mode (`'rb'` or `'r+b'`).

---

**Note:** If an object containing an unsupported type was marshalled with `dump()`, `load()` will substitute `None` for the unmarshallable type.

---

`marshal.dumps` (*value* [, *version* ])

Return the string that would be written to a file by `dump(value, file)`. The value must be a supported type. Raise a `ValueError` exception if value has (or contains an object that has) an unsupported type. New in version 2.4: The *version* argument indicates the data format that `dumps` should use (see below).

`marshal.loads` (*string*)

Convert the string to a value. If no valid value is found, raise `EOFError`, `ValueError` or `TypeError`. Extra characters in the string are ignored.

In addition, the following constants are defined:

`marshal.version`

Indicates the format that the module uses. Version 0 is the historical format, version 1 (added in Python 2.4)

shares interned strings and version 2 (added in Python 2.5) uses a binary format for floating point numbers. The current version is 2. New in version 2.4.

## 11.6 anydbm — Generic access to DBM-style databases

**Note:** The `anydbm` module has been renamed to `dbm` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

`anydbm` is a generic interface to variants of the DBM database — `dbhash` (requires `bsddb`), `gdbm`, or `dbm`. If none of these modules is installed, the slow-but-simple implementation in module `dumbdbm` will be used.

`anydbm.open(filename[, flag[, mode]])`

Open the database file *filename* and return a corresponding object.

If the database file already exists, the `whichdb` module is used to determine its type and the appropriate module is used; if it does not exist, the first module listed above that can be imported is used.

The optional *flag* argument must be one of these values:

Value	Meaning
'r'	Open existing database for reading only (default)
'w'	Open existing database for reading and writing
'c'	Open database for reading and writing, creating it if it doesn't exist
'n'	Always create a new, empty database, open for reading and writing

If not specified, the default value is 'r'.

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0666 (and will be modified by the prevailing `umask`).

**exception** `anydbm.error`

A tuple containing the exceptions that can be raised by each of the supported modules, with a unique exception also named `anydbm.error` as the first item — the latter is used when `anydbm.error` is raised.

The object returned by `open()` supports most of the same functionality as dictionaries; keys and their corresponding values can be stored, retrieved, and deleted, and the `has_key()` and `keys()` methods are available. Keys and values must always be strings.

The following example records some hostnames and a corresponding title, and then prints out the contents of the database:

```
import anydbm

# Open database, creating it if necessary.
db = anydbm.open('cache', 'c')

# Record some values
db['www.python.org'] = 'Python Website'
db['www.cnn.com'] = 'Cable News Network'

# Loop through contents. Other dictionary methods
# such as .keys(), .values() also work.
for k, v in db.iteritems():
    print k, '\t', v

# Storing a non-string key or value will raise an exception (most
```

```
# likely a TypeError).
db['www.yahoo.com'] = 4

# Close when done.
db.close()
```

**See Also:**

**Module `dbhash`** BSD db database interface.

**Module `dbm`** Standard Unix database interface.

**Module `dumbdbm`** Portable implementation of the `dbm` interface.

**Module `gdbm`** GNU database interface, based on the `dbm` interface.

**Module `shelve`** General object persistence built on top of the Python `dbm` interface.

**Module `whichdb`** Utility module used to determine the type of an existing database.

## 11.7 `whichdb` — Guess which DBM module created a database

**Note:** The `whichdb` module’s only function has been put into the `dbm` module in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

The single function in this module attempts to guess which of the several simple database modules available—`dbm`, `gdbm`, or `dbhash`—should be used to open a given file.

`whichdb.whichdb(filename)`

Returns one of the following values: `None` if the file can’t be opened because it’s unreadable or doesn’t exist; the empty string (`''`) if the file’s format can’t be guessed; or a string containing the required module name, such as `'dbm'` or `'gdbm'`.

## 11.8 `dbm` — Simple “database” interface

*Platforms:* Unix

**Note:** The `dbm` module has been renamed to `dbm.ndbm` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

The `dbm` module provides an interface to the Unix “(n)dbm” library. Dbm objects behave like mappings (dictionaries), except that keys and values are always strings. Printing a dbm object doesn’t print the keys and values, and the `items()` and `values()` methods are not supported.

This module can be used with the “classic” `ndbm` interface, the BSD DB compatibility interface, or the GNU GDBM compatibility interface. On Unix, the **configure** script will attempt to locate the appropriate header file to simplify building this module.

The module defines the following:

**exception `dbm.error`**

Raised on dbm-specific errors, such as I/O errors. `KeyError` is raised for general mapping errors like specifying an incorrect key.

**dbm.library**

Name of the `ndbm` implementation library used.

**dbm.open** (*filename* [, *flag* [, *mode* ] ])

Open a `dbm` database and return a `dbm` object. The *filename* argument is the name of the database file (without the `.dir` or `.pag` extensions; note that the BSD DB implementation of the interface will append the extension `.db` and only create one file).

The optional *flag* argument must be one of these values:

Value	Meaning
'r'	Open existing database for reading only (default)
'w'	Open existing database for reading and writing
'c'	Open database for reading and writing, creating it if it doesn't exist
'n'	Always create a new, empty database, open for reading and writing

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0666` (and will be modified by the prevailing `umask`).

**See Also:**

**Module `anydbm`** Generic interface to `dbm`-style databases.

**Module `gdbm`** Similar interface to the GNU GDBM library.

**Module `whichdb`** Utility module used to determine the type of an existing database.

## 11.9 `gdbm` — GNU's reinterpretation of `dbm`

*Platforms:* Unix

---

**Note:** The `gdbm` module has been renamed to `dbm.gnu` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

This module is quite similar to the `dbm` module, but uses `gdbm` instead to provide some additional functionality. Please note that the file formats created by `gdbm` and `dbm` are incompatible.

The `gdbm` module provides an interface to the GNU DBM library. `gdbm` objects behave like mappings (dictionaries), except that keys and values are always strings. Printing a `gdbm` object doesn't print the keys and values, and the `items()` and `values()` methods are not supported.

The module defines the following constant and functions:

**exception `gdbm.error`**

Raised on `gdbm`-specific errors, such as I/O errors. `KeyError` is raised for general mapping errors like specifying an incorrect key.

**`gdbm.open`** (*filename* [, *flag* [, *mode* ] ])

Open a `gdbm` database and return a `gdbm` object. The *filename* argument is the name of the database file.

The optional *flag* argument can be:

Value	Meaning
'r'	Open existing database for reading only (default)
'w'	Open existing database for reading and writing
'c'	Open database for reading and writing, creating it if it doesn't exist
'n'	Always create a new, empty database, open for reading and writing

The following additional characters may be appended to the *flag* to control how the database is opened:

Value	Meaning
'f'	Open the database in fast mode. Writes to the database will not be synchronized.
's'	Synchronized mode. This will cause changes to the database to be immediately written to the file.
'u'	Do not lock database.

Not all flags are valid for all versions of `gdbm`. The module constant `open_flags` is a string of supported flag characters. The exception `error` is raised if an invalid flag is specified.

The optional `mode` argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0666`.

In addition to the dictionary-like methods, `gdbm` objects have the following methods:

`gdbm.firstkey()`

It's possible to loop over every key in the database using this method and the `nextkey()` method. The traversal is ordered by `gdbm`'s internal hash values, and won't be sorted by the key values. This method returns the starting key.

`gdbm.nextkey(key)`

Returns the key that follows `key` in the traversal. The following code prints every key in the database `db`, without having to create a list in memory that contains them all:

```
k = db.firstkey()
while k != None:
    print k
    k = db.nextkey(k)
```

`gdbm.reorganize()`

If you have carried out a lot of deletions and would like to shrink the space used by the `gdbm` file, this routine will reorganize the database. `gdbm` will not shorten the length of a database file except by using this reorganization; otherwise, deleted file space will be kept and reused as new (key, value) pairs are added.

`gdbm.sync()`

When the database has been opened in fast mode, this method forces any unwritten data to be written to the disk.

**See Also:**

**Module `anydbm`** Generic interface to dbm-style databases.

**Module `whichdb`** Utility module used to determine the type of an existing database.

## 11.10 `dbhash` — DBM-style interface to the BSD database library

Deprecated since version 2.6: The `dbhash` module has been removed in Python 3. The `dbhash` module provides a function to open databases using the BSD `db` library. This module mirrors the interface of the other Python database modules that provide access to DBM-style databases. The `bsddb` module is required to use `dbhash`.

This module provides an exception and a function:

**exception `dbhash.error`**

Exception raised on database errors other than `KeyError`. It is a synonym for `bsddb.error`.

`dbhash.open(path[, flag[, mode]])`

Open a `db` database and return the database object. The `path` argument is the name of the database file.

The `flag` argument can be:

Value	Meaning
'r'	Open existing database for reading only (default)
'w'	Open existing database for reading and writing
'c'	Open database for reading and writing, creating it if it doesn't exist
'n'	Always create a new, empty database, open for reading and writing

For platforms on which the BSD `db` library supports locking, an `'l'` can be appended to indicate that locking should be used.

The optional `mode` parameter is used to indicate the Unix permission bits that should be set if a new database must be created; this will be masked by the current `umask` value for the process.

**See Also:**

**Module `anydbm`** Generic interface to dbm-style databases.

**Module `bsddb`** Lower-level interface to the BSD `db` library.

**Module `whichdb`** Utility module used to determine the type of an existing database.

### 11.10.1 Database Objects

The database objects returned by `open()` provide the methods common to all the DBM-style databases and mapping objects. The following methods are available in addition to the standard methods.

`dbhash.first()`

It's possible to loop over every key/value pair in the database using this method and the `next()` method. The traversal is ordered by the databases internal hash values, and won't be sorted by the key values. This method returns the starting key.

`dbhash.last()`

Return the last key/value pair in a database traversal. This may be used to begin a reverse-order traversal; see `previous()`.

`dbhash.next()`

Returns the key next key/value pair in a database traversal. The following code prints every key in the database `db`, without having to create a list in memory that contains them all:

```
print db.first()
for i in xrange(1, len(db)):
    print db.next()
```

`dbhash.previous()`

Returns the previous key/value pair in a forward-traversal of the database. In conjunction with `last()`, this may be used to implement a reverse-order traversal.

`dbhash.sync()`

This method forces any unwritten data to be written to the disk.

## 11.11 `bsddb` — Interface to Berkeley DB library

Deprecated since version 2.6: The `bsddb` module has been removed in Python 3. The `bsddb` module provides an interface to the Berkeley DB library. Users can create hash, btree or record based library files using the appropriate open call. `Bsddb` objects behave generally like dictionaries. Keys and values must be strings, however, so to use other objects as keys or to store other kinds of objects the user must serialize them somehow, typically using `marshal.dumps()` or `pickle.dumps()`.

The `bsddb` module requires a Berkeley DB library version from 4.0 thru 4.7.

**See Also:**

<http://www.jcea.es/programacion/pybsddb.htm> The website with documentation for the `bsddb.db` Python Berkeley DB interface that closely mirrors the object oriented interface provided in Berkeley DB 4.x itself.

<http://www.oracle.com/database/berkeley-db/> The Berkeley DB library.

A more modern DB, DBEnv and DBSequence object interface is available in the `bsddb.db` module which closely matches the Berkeley DB C API documented at the above URLs. Additional features provided by the `bsddb.db` API include fine tuning, transactions, logging, and multiprocess concurrent database access.

The following is a description of the legacy `bsddb` interface compatible with the old Python `bsddb` module. Starting in Python 2.5 this interface should be safe for multithreaded access. The `bsddb.db` API is recommended for threading users as it provides better control.

The `bsddb` module defines the following functions that create objects that access the appropriate type of Berkeley DB file. The first two arguments of each function are the same. For ease of portability, only the first two arguments should be used in most instances.

```
bsddb.hashopen(filename[, flag[, mode[, pgsz[, ffactor[, nelem[, cachesize[, lorder[, hflags ]]]]]]])
```

Open the hash format file named *filename*. Files never intended to be preserved on disk may be created by passing `None` as the *filename*. The optional *flag* identifies the mode used to open the file. It may be `'r'` (read only), `'w'` (read-write), `'c'` (read-write - create if necessary; the default) or `'n'` (read-write - truncate to zero length). The other arguments are rarely used and are just passed to the low-level `dbopen()` function. Consult the Berkeley DB documentation for their use and interpretation.

```
bsddb.btopen(filename[, flag[, mode[, btflags[, cachesize[, maxkeypage[, minkeypage[, pgsz[, lorder ]]]]]]])
```

Open the btree format file named *filename*. Files never intended to be preserved on disk may be created by passing `None` as the *filename*. The optional *flag* identifies the mode used to open the file. It may be `'r'` (read only), `'w'` (read-write), `'c'` (read-write - create if necessary; the default) or `'n'` (read-write - truncate to zero length). The other arguments are rarely used and are just passed to the low-level `dbopen` function. Consult the Berkeley DB documentation for their use and interpretation.

```
bsddb.rnopen(filename[, flag[, mode[, rnflags[, cachesize[, pgsz[, lorder[, rlen[, delim[, source[, pad ]]]]]]]]])
```

Open a DB record format file named *filename*. Files never intended to be preserved on disk may be created by passing `None` as the *filename*. The optional *flag* identifies the mode used to open the file. It may be `'r'` (read only), `'w'` (read-write), `'c'` (read-write - create if necessary; the default) or `'n'` (read-write - truncate to zero length). The other arguments are rarely used and are just passed to the low-level `dbopen` function. Consult the Berkeley DB documentation for their use and interpretation.

---

**Note:** Beginning in 2.3 some Unix versions of Python may have a `bsddb185` module. This is present *only* to allow backwards compatibility with systems which ship with the old Berkeley DB 1.85 database library. The `bsddb185` module should never be used directly in new code. The module has been removed in Python 3. If you find you still need it look in PyPI.

---

**See Also:**

**Module `dbhash`** DBM-style interface to the `bsddb`

### 11.11.1 Hash, BTree and Record Objects

Once instantiated, hash, btree and record objects support the same methods as dictionaries. In addition, they support the methods listed below. Changed in version 2.3.1: Added dictionary methods.

`bsddbobject.close()`  
Close the underlying file. The object can no longer be accessed. Since there is no `open()` method for these objects, to open the file again a new `bsddb` module open function must be called.

`bsddbobject.keys()`  
Return the list of keys contained in the DB file. The order of the list is unspecified and should not be relied on. In particular, the order of the list returned is different for different file formats.

`bsddbobject.has_key(key)`  
Return 1 if the DB file contains the argument as a key.

`bsddbobject.set_location(key)`  
Set the cursor to the item indicated by `key` and return a tuple containing the key and its value. For binary tree databases (opened using `btopen()`), if `key` does not actually exist in the database, the cursor will point to the next item in sorted order and return that key and value. For other databases, `KeyError` will be raised if `key` is not found in the database.

`bsddbobject.first()`  
Set the cursor to the first item in the DB file and return it. The order of keys in the file is unspecified, except in the case of B-Tree databases. This method raises `bsddb.error` if the database is empty.

`bsddbobject.next()`  
Set the cursor to the next item in the DB file and return it. The order of keys in the file is unspecified, except in the case of B-Tree databases.

`bsddbobject.previous()`  
Set the cursor to the previous item in the DB file and return it. The order of keys in the file is unspecified, except in the case of B-Tree databases. This is not supported on hashtable databases (those opened with `hashopen()`).

`bsddbobject.last()`  
Set the cursor to the last item in the DB file and return it. The order of keys in the file is unspecified. This is not supported on hashtable databases (those opened with `hashopen()`). This method raises `bsddb.error` if the database is empty.

`bsddbobject.sync()`  
Synchronize the database on disk.

Example:

```
>>> import bsddb
>>> db = bsddb.btopen('/tmp/spam.db', 'c')
>>> for i in range(10): db['%d'%i] = '%d' % (i*i)
...
>>> db['3']
'9'
>>> db.keys()
['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
>>> db.first()
('0', '0')
>>> db.next()
('1', '1')
>>> db.last()
('9', '81')
>>> db.set_location('2')
('2', '4')
>>> db.previous()
('1', '1')
>>> for k, v in db.iteritems():
```

```

...     print k, v
0 0
1 1
2 4
3 9
4 16
5 25
6 36
7 49
8 64
9 81
>>> '8' in db
True
>>> db.sync()
0

```

## 11.12 dumbdbm — Portable DBM implementation

---

**Note:** The `dumbdbm` module has been renamed to `dbm.dumb` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

**Note:** The `dumbdbm` module is intended as a last resort fallback for the `anydbm` module when no more robust module is available. The `dumbdbm` module is not written for speed and is not nearly as heavily used as the other database modules.

---

The `dumbdbm` module provides a persistent dictionary-like interface which is written entirely in Python. Unlike other modules such as `gdbm` and `bsddb`, no external library is required. As with other persistent mappings, the keys and values must always be strings.

The module defines the following:

**exception** `dumbdbm.error`

Raised on `dumbdbm`-specific errors, such as I/O errors. `KeyError` is raised for general mapping errors like specifying an incorrect key.

`dumbdbm.open(filename[, flag[, mode]])`

Open a `dumbdbm` database and return a `dumbdbm` object. The *filename* argument is the basename of the database file (without any specific extensions). When a `dumbdbm` database is created, files with `.dat` and `.dir` extensions are created.

The optional *flag* argument is currently ignored; the database is always opened for update, and will be created if it does not exist.

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0666` (and will be modified by the prevailing `umask`). Changed in version 2.2: The *mode* argument was ignored in earlier versions.

**See Also:**

**Module** `anydbm` Generic interface to `dbm`-style databases.

**Module** `dbm` Similar interface to the `DBM/NDBM` library.

**Module** `gdbm` Similar interface to the GNU `GDBM` library.

**Module `shelve`** Persistence module which stores non-string data.

**Module `whichdb`** Utility module used to determine the type of an existing database.

### 11.12.1 Dumbdbm Objects

In addition to the methods provided by the `UserDict.DictMixin` class, `dumbdbm` objects provide the following methods.

`dumbdbm.sync()`  
Synchronize the on-disk directory and data files. This method is called by the `sync()` method of `Shelve` objects.

## 11.13 `sqlite3` — DB-API 2.0 interface for SQLite databases

New in version 2.5. SQLite is a C library that provides a lightweight disk-based database that doesn't require a separate server process and allows accessing the database using a nonstandard variant of the SQL query language. Some applications can use SQLite for internal data storage. It's also possible to prototype an application using SQLite and then port the code to a larger database such as PostgreSQL or Oracle.

The `sqlite3` module was written by Gerhard Häring. It provides a SQL interface compliant with the DB-API 2.0 specification described by [PEP 249](#).

To use the module, you must first create a `Connection` object that represents the database. Here the data will be stored in the `example.db` file:

```
import sqlite3
conn = sqlite3.connect('example.db')
```

You can also supply the special name `:memory:` to create a database in RAM.

Once you have a `Connection`, you can create a `Cursor` object and call its `execute()` method to perform SQL commands:

```
c = conn.cursor()

# Create table
c.execute("""CREATE TABLE stocks
           (date text, trans text, symbol text, qty real, price real)""")

# Insert a row of data
c.execute("INSERT INTO stocks VALUES ('2006-01-05','BUY','RHAT',100,35.14)")

# Save (commit) the changes
conn.commit()

# We can also close the cursor if we are done with it
c.close()
```

The data you've saved is persistent and is available in subsequent sessions:

```
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor()
```

Usually your SQL operations will need to use values from Python variables. You shouldn't assemble your query using Python's string operations because doing so is insecure; it makes your program vulnerable to an SQL injection attack (see <http://xkcd.com/327/> for humorous example of what can go wrong).

Instead, use the DB-API's parameter substitution. Put `?` as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor's `execute()` method. (Other database modules may use a different placeholder, such as `%s` or `:1`.) For example:

```
# Never do this -- insecure!
symbol = 'RHAT'
c.execute("SELECT * FROM stocks WHERE symbol = '%s'" % symbol)

# Do this instead
t = ('RHAT',)
c.execute('SELECT * FROM stocks WHERE symbol=?', t)
print c.fetchone()

# Larger example that inserts many records at a time
purchases = [('2006-03-28', 'BUY', 'IBM', 1000, 45.00),
              ('2006-04-05', 'BUY', 'MSFT', 1000, 72.00),
              ('2006-04-06', 'SELL', 'IBM', 500, 53.00),
              ]
c.executemany('INSERT INTO stocks VALUES (?, ?, ?, ?, ?)', purchases)
```

To retrieve data after executing a `SELECT` statement, you can either treat the cursor as an *iterator*, call the cursor's `fetchone()` method to retrieve a single matching row, or call `fetchall()` to get a list of the matching rows.

This example uses the iterator form:

```
>>> for row in c.execute('SELECT * FROM stocks ORDER BY price'):
        print row

(u'2006-01-05', u'BUY', u'RHAT', 100, 35.14)
(u'2006-03-28', u'BUY', u'IBM', 1000, 45.0)
(u'2006-04-06', u'SELL', u'IBM', 500, 53.0)
(u'2006-04-05', u'BUY', u'MSFT', 1000, 72.0)
```

#### See Also:

<http://code.google.com/p/pysqlite/> The `pysqlite` web page – `sqlite3` is developed externally under the name “`pysqlite`”.

<http://www.sqlite.org> The `SQLite` web page; the documentation describes the syntax and the available data types for the supported SQL dialect.

<http://www.w3schools.com/sql/> Tutorial, reference and examples for learning SQL syntax.

**PEP 249 - Database API Specification 2.0** PEP written by Marc-André Lemburg.

## 11.13.1 Module functions and constants

### `sqlite3.PARSE_DECLTYPES`

This constant is meant to be used with the `detect_types` parameter of the `connect()` function.

Setting it makes the `sqlite3` module parse the declared type for each column it returns. It will parse out the first word of the declared type, i. e. for “integer primary key”, it will parse out “integer”, or for “number(10)” it will parse out “number”. Then for that column, it will look into the `converters` dictionary and use the converter function registered for that type there.

**sqlite3.PARSE\_COLNAMES**

This constant is meant to be used with the *detect\_types* parameter of the `connect()` function.

Setting this makes the SQLite interface parse the column name for each column it returns. It will look for a string formed `[mytype]` in there, and then decide that 'mytype' is the type of the column. It will try to find an entry of 'mytype' in the converters dictionary and then use the converter function found there to return the value. The column name found in `Cursor.description` is only the first word of the column name, i. e. if you use something like 'as "x [datetime]"' in your SQL, then we will parse out everything until the first blank for the column name: the column name would simply be "x".

**sqlite3.connect**(*database* [, *timeout*, *detect\_types*, *isolation\_level*, *check\_same\_thread*, *factory*,  
*cached\_statements* ])

Opens a connection to the SQLite database file *database*. You can use `":memory:"` to open a database connection to a database that resides in RAM instead of on disk.

When a database is accessed by multiple connections, and one of the processes modifies the database, the SQLite database is locked until that transaction is committed. The *timeout* parameter specifies how long the connection should wait for the lock to go away until raising an exception. The default for the timeout parameter is 5.0 (five seconds).

For the *isolation\_level* parameter, please see the `Connection.isolation_level` property of `Connection` objects.

SQLite natively supports only the types TEXT, INTEGER, FLOAT, BLOB and NULL. If you want to use other types you must add support for them yourself. The *detect\_types* parameter and the using custom **converters** registered with the module-level `register_converter()` function allow you to easily do that.

*detect\_types* defaults to 0 (i. e. off, no type detection), you can set it to any combination of `PARSE_DECLTYPES` and `PARSE_COLNAMES` to turn type detection on.

By default, the `sqlite3` module uses its `Connection` class for the connect call. You can, however, subclass the `Connection` class and make `connect()` use your class instead by providing your class for the *factory* parameter.

Consult the section *SQLite and Python types* of this manual for details.

The `sqlite3` module internally uses a statement cache to avoid SQL parsing overhead. If you want to explicitly set the number of statements that are cached for the connection, you can set the *cached\_statements* parameter. The currently implemented default is to cache 100 statements.

**sqlite3.register\_converter**(*typename*, *callable*)

Registers a callable to convert a bytestring from the database into a custom Python type. The callable will be invoked for all database values that are of the type *typename*. Confer the parameter *detect\_types* of the `connect()` function for how the type detection works. Note that the case of *typename* and the name of the type in your query must match!

**sqlite3.register\_adapter**(*type*, *callable*)

Registers a callable to convert the custom Python type *type* into one of SQLite's supported types. The callable *callable* accepts as single parameter the Python value, and must return a value of the following types: int, long, float, str (UTF-8 encoded), unicode or buffer.

**sqlite3.complete\_statement**(*sql*)

Returns `True` if the string *sql* contains one or more complete SQL statements terminated by semicolons. It does not verify that the SQL is syntactically correct, only that there are no unclosed string literals and the statement is terminated by a semicolon.

This can be used to build a shell for SQLite, as in the following example:

```
# A minimal SQLite shell for experiments

import sqlite3
```

```

con = sqlite3.connect(":memory:")
con.isolation_level = None
cur = con.cursor()

buffer = ""

print "Enter your SQL commands to execute in sqlite3."
print "Enter a blank line to exit."

while True:
    line = raw_input()
    if line == "":
        break
    buffer += line
    if sqlite3.complete_statement(buffer):
        try:
            buffer = buffer.strip()
            cur.execute(buffer)

            if buffer.lstrip().upper().startswith("SELECT"):
                print cur.fetchall()
        except sqlite3.Error, e:
            print "An error occurred:", e.args[0]
        buffer = ""

con.close()

```

`sqlite3.enable_callback_tracebacks(flag)`

By default you will not get any tracebacks in user-defined functions, aggregates, converters, authorizer callbacks etc. If you want to debug them, you can call this function with *flag* as `True`. Afterwards, you will get tracebacks from callbacks on `sys.stderr`. Use `False` to disable the feature again.

## 11.13.2 Connection Objects

**class** `sqlite3.Connection`

A SQLite database connection has the following attributes and methods:

`Connection.isolation_level`

Get or set the current isolation level. `None` for autocommit mode or one of “DEFERRED”, “IMMEDIATE” or “EXCLUSIVE”. See section *Controlling Transactions* for a more detailed explanation.

`Connection.cursor([cursorClass])`

The `cursor` method accepts a single optional parameter *cursorClass*. If supplied, this must be a custom cursor class that extends `sqlite3.Cursor`.

`Connection.commit()`

This method commits the current transaction. If you don’t call this method, anything you did since the last call to `commit()` is not visible from other database connections. If you wonder why you don’t see the data you’ve written to the database, please check you didn’t forget to call this method.

`Connection.rollback()`

This method rolls back any changes to the database since the last call to `commit()`.

`Connection.close()`

This closes the database connection. Note that this does not automatically call `commit()`. If you just close

your database connection without calling `commit()` first, your changes will be lost!

`Connection.execute(sql[, parameters])`

This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor's `execute` method with the parameters given.

`Connection.executemany(sql[, parameters])`

This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor's `executemany` method with the parameters given.

`Connection.executescript(sql_script)`

This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor's `executescript` method with the parameters given.

`Connection.create_function(name, num_params, func)`

Creates a user-defined function that you can later use from within SQL statements under the function name *name*. *num\_params* is the number of parameters the function accepts, and *func* is a Python callable that is called as the SQL function.

The function can return any of the types supported by SQLite: unicode, str, int, long, float, buffer and None.

Example:

```
import sqlite3
import md5

def md5sum(t):
    return md5.md5(t).hexdigest()

con = sqlite3.connect(":memory:")
con.create_function("md5", 1, md5sum)
cur = con.cursor()
cur.execute("select md5(?)", ("foo",))
print cur.fetchone()[0]
```

`Connection.create_aggregate(name, num_params, aggregate_class)`

Creates a user-defined aggregate function.

The aggregate class must implement a `step` method, which accepts the number of parameters *num\_params*, and a `finalize` method which will return the final result of the aggregate.

The `finalize` method can return any of the types supported by SQLite: unicode, str, int, long, float, buffer and None.

Example:

```
import sqlite3

class MySum:
    def __init__(self):
        self.count = 0

    def step(self, value):
        self.count += value

    def finalize(self):
        return self.count
```

```

con = sqlite3.connect(":memory:")
con.create_aggregate("mysum", 1, MySum)
cur = con.cursor()
cur.execute("create table test(i)")
cur.execute("insert into test(i) values (1)")
cur.execute("insert into test(i) values (2)")
cur.execute("select mysum(i) from test")
print cur.fetchone()[0]

```

Connection.**create\_collation**(*name*, *callable*)

Creates a collation with the specified *name* and *callable*. The callable will be passed two string arguments. It should return -1 if the first is ordered lower than the second, 0 if they are ordered equal and 1 if the first is ordered higher than the second. Note that this controls sorting (ORDER BY in SQL) so your comparisons don't affect other SQL operations.

Note that the callable will get its parameters as Python bytestrings, which will normally be encoded in UTF-8.

The following example shows a custom collation that sorts “the wrong way”:

```

import sqlite3

def collate_reverse(string1, string2):
    return -cmp(string1, string2)

con = sqlite3.connect(":memory:")
con.create_collation("reverse", collate_reverse)

cur = con.cursor()
cur.execute("create table test(x)")
cur.executemany("insert into test(x) values (?)", [("a",), ("b",)])
cur.execute("select x from test order by x collate reverse")
for row in cur:
    print row
con.close()

```

To remove a collation, call `create_collation` with `None` as callable:

```
con.create_collation("reverse", None)
```

Connection.**interrupt**()

You can call this method from a different thread to abort any queries that might be executing on the connection. The query will then abort and the caller will get an exception.

Connection.**set\_authorizer**(*authorizer\_callback*)

This routine registers a callback. The callback is invoked for each attempt to access a column of a table in the database. The callback should return `SQLITE_OK` if access is allowed, `SQLITE_DENY` if the entire SQL statement should be aborted with an error and `SQLITE_IGNORE` if the column should be treated as a NULL value. These constants are available in the `sqlite3` module.

The first argument to the callback signifies what kind of operation is to be authorized. The second and third argument will be arguments or `None` depending on the first argument. The 4th argument is the name of the database (“main”, “temp”, etc.) if applicable. The 5th argument is the name of the inner-most trigger or view that is responsible for the access attempt or `None` if this access attempt is directly from input SQL code.

Please consult the SQLite documentation about the possible values for the first argument and the meaning of the second and third argument depending on the first one. All necessary constants are available in the `sqlite3`

module.

`Connection.set_progress_handler` (*handler*, *n*)

This routine registers a callback. The callback is invoked for every *n* instructions of the SQLite virtual machine. This is useful if you want to get called from SQLite during long-running operations, for example to update a GUI.

If you want to clear any previously installed progress handler, call the method with `None` for *handler*. New in version 2.6.

`Connection.enable_load_extension` (*enabled*)

This routine allows/disallows the SQLite engine to load SQLite extensions from shared libraries. SQLite extensions can define new functions, aggregates or whole new virtual table implementations. One well-known extension is the fulltext-search extension distributed with SQLite.

Loadable extensions are disabled by default. See <sup>12</sup>. New in version 2.7.

```
import sqlite3
```

```
con = sqlite3.connect(":memory:")
```

```
# enable extension loading
con.enable_load_extension(True)
```

```
# Load the fulltext search extension
con.execute("select load_extension('./fts3.so')")
```

```
# alternatively you can load the extension using an API call:
# con.load_extension("./fts3.so")
```

```
# disable extension loading again
con.enable_load_extension(False)
```

```
# example from SQLite wiki
```

```
con.execute("create virtual table recipe using fts3(name, ingredients)")
con.executescript("""
```

```
    insert into recipe (name, ingredients) values ('broccoli stew', 'broccoli peppers
    insert into recipe (name, ingredients) values ('pumpkin stew', 'pumpkin onions gar
    insert into recipe (name, ingredients) values ('broccoli pie', 'broccoli cheese on
    insert into recipe (name, ingredients) values ('pumpkin pie', 'pumpkin sugar flour
    """)
```

```
for row in con.execute("select rowid, name, ingredients from recipe where name match 'p
print row
```

`Connection.load_extension` (*path*)

This routine loads a SQLite extension from a shared library. You have to enable extension loading with `enable_load_extension()` before you can use this routine.

Loadable extensions are disabled by default. See <sup>1</sup>. New in version 2.7.

`Connection.row_factory`

You can change this attribute to a callable that accepts the cursor and the original row as a tuple and will return the real result row. This way, you can implement more advanced ways of returning results, such as returning an object that can also access columns by name.

---

<sup>12</sup> The `sqlite3` module is not built with loadable extension support by default, because some platforms (notably Mac OS X) have SQLite libraries which are compiled without this feature. To get loadable extension support, you must modify `setup.py` and remove the line that sets `SQLITE_OMIT_LOAD_EXTENSION`.

Example:

```
import sqlite3

def dict_factory(cursor, row):
    d = {}
    for idx, col in enumerate(cursor.description):
        d[col[0]] = row[idx]
    return d

con = sqlite3.connect(":memory:")
con.row_factory = dict_factory
cur = con.cursor()
cur.execute("select 1 as a")
print cur.fetchone() ["a"]
```

If returning a tuple doesn't suffice and you want name-based access to columns, you should consider setting `row_factory` to the highly-optimized `sqlite3.Row` type. `Row` provides both index-based and case-insensitive name-based access to columns with almost no memory overhead. It will probably be better than your own custom dictionary-based approach or even a `db_row` based solution.

#### Connection.`text_factory`

Using this attribute you can control what objects are returned for the TEXT data type. By default, this attribute is set to `unicode` and the `sqlite3` module will return Unicode objects for TEXT. If you want to return bytestrings instead, you can set it to `str`.

For efficiency reasons, there's also a way to return Unicode objects only for non-ASCII data, and bytestrings otherwise. To activate it, set this attribute to `sqlite3.OptimizedUnicode`.

You can also set it to any other callable that accepts a single bytestring parameter and returns the resulting object.

See the following example code for illustration:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()

AUSTRIA = u"\xd6sterreich"

# by default, rows are returned as Unicode
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert row[0] == AUSTRIA

# but we can make sqlite3 always return bytestrings ...
con.text_factory = str
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert type(row[0]) is str
# the bytestrings will be encoded in UTF-8, unless you stored garbage in the
# database ...
assert row[0] == AUSTRIA.encode("utf-8")

# we can also implement a custom text_factory ...
# here we implement one that will ignore Unicode characters that cannot be
```

```
# decoded from UTF-8
con.text_factory = lambda x: unicode(x, "utf-8", "ignore")
cur.execute("select ?", ("this is latin1 and would normally create errors" +
                        u"\xe4\xfc".encode("latin1"),))

row = cur.fetchone()
assert type(row[0]) is unicode

# sqlite3 offers a built-in optimized text_factory that will return bytestring
# objects, if the data is in ASCII only, and otherwise return unicode objects
con.text_factory = sqlite3.OptimizedUnicode
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert type(row[0]) is unicode

cur.execute("select ?", ("Germany",))
row = cur.fetchone()
assert type(row[0]) is str
```

**Connection.total\_changes**

Returns the total number of database rows that have been modified, inserted, or deleted since the database connection was opened.

**Connection.iterdump**

Returns an iterator to dump the database in an SQL text format. Useful when saving an in-memory database for later restoration. This function provides the same capabilities as the `.dump` command in the **sqlite3** shell. New in version 2.6. Example:

```
# Convert file existing_db.db to SQL dump file dump.sql
import sqlite3, os

con = sqlite3.connect('existing_db.db')
with open('dump.sql', 'w') as f:
    for line in con.iterdump():
        f.write('%s\n' % line)
```

### 11.13.3 Cursor Objects

**class sqlite3.Cursor**

A `Cursor` instance has the following attributes and methods.

**Cursor.execute**(*sql*[, *parameters*])

Executes an SQL statement. The SQL statement may be parameterized (i. e. placeholders instead of SQL literals). The `sqlite3` module supports two kinds of placeholders: question marks (qmark style) and named placeholders (named style).

Here's an example of both styles:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table people (name_last, age)")

who = "Yeltsin"
age = 72
```

```

# This is the qmark style:
cur.execute("insert into people values (?, ?)", (who, age))

# And this is the named style:
cur.execute("select * from people where name_last=:who and age=:age", {"who": who, "age": age})

print cur.fetchone()

```

`execute()` will only execute a single SQL statement. If you try to execute more than one statement with it, it will raise a `Warning`. Use `executescript()` if you want to execute multiple SQL statements with one call.

Cursor.**executemany**(*sql*, *seq\_of\_parameters*)

Executes an SQL command against all parameter sequences or mappings found in the sequence *sql*. The `sqlite3` module also allows using an *iterator* yielding parameters instead of a sequence.

```

import sqlite3

class IterChars:
    def __init__(self):
        self.count = ord('a')

    def __iter__(self):
        return self

    def next(self):
        if self.count > ord('z'):
            raise StopIteration
        self.count += 1
        return (chr(self.count - 1),) # this is a 1-tuple

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

theIter = IterChars()
cur.executemany("insert into characters(c) values (?)", theIter)

cur.execute("select c from characters")
print cur.fetchall()

```

Here's a shorter example using a *generator*:

```

import sqlite3
import string

def char_generator():
    for c in string.lowercase:
        yield (c,)

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

```

```
cur.executemany("insert into characters(c) values (?)", char_generator())

cur.execute("select c from characters")
print cur.fetchall()
```

Cursor.**executescript** (*sql\_script*)

This is a nonstandard convenience method for executing multiple SQL statements at once. It issues a COMMIT statement first, then executes the SQL script it gets as a parameter.

*sql\_script* can be a bytestring or a Unicode string.

Example:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.executescript("""
    create table person(
        firstname,
        lastname,
        age
    );

    create table book(
        title,
        author,
        published
    );

    insert into book(title, author, published)
    values (
        'Dirk Gently''s Holistic Detective Agency',
        'Douglas Adams',
        1987
    );
""")
```

Cursor.**fetchone** ()

Fetches the next row of a query result set, returning a single sequence, or `None` when no more data is available.

Cursor.**fetchmany** ([*size=cursor.arraysize* ])

Fetches the next set of rows of a query result, returning a list. An empty list is returned when no more rows are available.

The number of rows to fetch per call is specified by the *size* parameter. If it is not given, the cursor's `arraysize` determines the number of rows to be fetched. The method should try to fetch as many rows as indicated by the *size* parameter. If this is not possible due to the specified number of rows not being available, fewer rows may be returned.

Note there are performance considerations involved with the *size* parameter. For optimal performance, it is usually best to use the `arraysize` attribute. If the *size* parameter is used, then it is best for it to retain the same value from one `fetchmany()` call to the next.

Cursor.**fetchall** ()

Fetches all (remaining) rows of a query result, returning a list. Note that the cursor's `arraysize` attribute can affect the performance of this operation. An empty list is returned when no rows are available.

**Cursor.rowcount**

Although the `Cursor` class of the `sqlite3` module implements this attribute, the database engine's own support for the determination of "rows affected"/"rows selected" is quirky.

For `executemany()` statements, the number of modifications are summed up into `rowcount`.

As required by the Python DB API Spec, the `rowcount` attribute "is -1 in case no `executeXX()` has been performed on the cursor or the rowcount of the last operation is not determinable by the interface". This includes `SELECT` statements because we cannot determine the number of rows a query produced until all rows were fetched.

With SQLite versions before 3.6.5, `rowcount` is set to 0 if you make a `DELETE FROM table` without any condition.

**Cursor.lastrowid**

This read-only attribute provides the rowid of the last modified row. It is only set if you issued a `INSERT` statement using the `execute()` method. For operations other than `INSERT` or when `executemany()` is called, `lastrowid` is set to `None`.

**Cursor.description**

This read-only attribute provides the column names of the last query. To remain compatible with the Python DB API, it returns a 7-tuple for each column where the last six items of each tuple are `None`.

It is set for `SELECT` statements without any matching rows as well.

## 11.13.4 Row Objects

**class sqlite3.Row**

A `Row` instance serves as a highly optimized `row_factory` for `Connection` objects. It tries to mimic a tuple in most of its features.

It supports mapping access by column name and index, iteration, representation, equality testing and `len()`.

If two `Row` objects have exactly the same columns and their members are equal, they compare equal. Changed in version 2.6: Added iteration and equality (hashability).

**keys()**

This method returns a tuple of column names. Immediately after a query, it is the first member of each tuple in `Cursor.description`. New in version 2.6.

Let's assume we initialize a table as in the example given above:

```
conn = sqlite3.connect(":memory:")
c = conn.cursor()
c.execute('''create table stocks
(date text, trans text, symbol text,
qty real, price real)''')
c.execute("""insert into stocks
          values ('2006-01-05', 'BUY', 'RHAT', 100, 35.14) """)
conn.commit()
c.close()
```

Now we plug `Row` in:

```
>>> conn.row_factory = sqlite3.Row
>>> c = conn.cursor()
>>> c.execute('select * from stocks')
<sqlite3.Cursor object at 0x7f4e7dd8fa80>
>>> r = c.fetchone()
>>> type(r)
```

```
<type 'sqlite3.Row'>
>>> r
(u'2006-01-05', u'BUY', u'RHAT', 100.0, 35.14)
>>> len(r)
5
>>> r[2]
u'RHAT'
>>> r.keys()
['date', 'trans', 'symbol', 'qty', 'price']
>>> r['qty']
100.0
>>> for member in r:
...     print member
...
2006-01-05
BUY
RHAT
100.0
35.14
```

### 11.13.5 SQLite and Python types

#### Introduction

SQLite natively supports the following types: NULL, INTEGER, REAL, TEXT, BLOB.

The following Python types can thus be sent to SQLite without any problem:

Python type	SQLite type
None	NULL
int	INTEGER
long	INTEGER
float	REAL
str (UTF8-encoded)	TEXT
unicode	TEXT
buffer	BLOB

This is how SQLite types are converted to Python types by default:

SQLite type	Python type
NULL	None
INTEGER	int or long, depending on size
REAL	float
TEXT	depends on text_factory, unicode by default
BLOB	buffer

The type system of the `sqlite3` module is extensible in two ways: you can store additional Python types in a SQLite database via object adaptation, and you can let the `sqlite3` module convert SQLite types to different Python types via converters.

#### Using adapters to store additional Python types in SQLite databases

As described before, SQLite supports only a limited set of types natively. To use other Python types with SQLite, you must **adapt** them to one of the `sqlite3` module's supported types for SQLite: one of `NoneType`, `int`, `long`, `float`, `str`, `unicode`, `buffer`.

The `sqlite3` module uses Python object adaptation, as described in

[PEP 246](#) for this. The protocol to use is `PrepareProtocol`.

There are two ways to enable the `sqlite3` module to adapt a custom Python type to one of the supported ones.

### Letting your object adapt itself

This is a good approach if you write the class yourself. Let's suppose you have a class like this:

```
class Point(object):
    def __init__(self, x, y):
        self.x, self.y = x, y
```

Now you want to store the point in a single SQLite column. First you'll have to choose one of the supported types first to be used for representing the point. Let's just use `str` and separate the coordinates using a semicolon. Then you need to give your class a method `__conform__(self, protocol)` which must return the converted value. The parameter `protocol` will be `PrepareProtocol`.

```
import sqlite3

class Point(object):
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __conform__(self, protocol):
        if protocol is sqlite3.PrepareProtocol:
            return "%f;%f" % (self.x, self.y)
```

```
con = sqlite3.connect(":memory:")
cur = con.cursor()
```

```
p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print cur.fetchone()[0]
```

### Registering an adapter callable

The other possibility is to create a function that converts the type to the string representation and register the function with `register_adapter()`.

---

**Note:** The type/class to adapt must be a *new-style class*, i. e. it must have `object` as one of its bases.

---

```
import sqlite3

class Point(object):
    def __init__(self, x, y):
        self.x, self.y = x, y

def adapt_point(point):
    return "%f;%f" % (point.x, point.y)

sqlite3.register_adapter(Point, adapt_point)
```

```
con = sqlite3.connect(":memory:")
cur = con.cursor()
```

```
p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print cur.fetchone()[0]
```

The `sqlite3` module has two default adapters for Python's built-in `datetime.date` and `datetime.datetime` types. Now let's suppose we want to store `datetime.datetime` objects not in ISO representation, but as a Unix timestamp.

```
import sqlite3
import datetime, time

def adapt_datetime(ts):
    return time.mktime(ts.timetuple())

sqlite3.register_adapter(datetime.datetime, adapt_datetime)

con = sqlite3.connect(":memory:")
cur = con.cursor()

now = datetime.datetime.now()
cur.execute("select ?", (now,))
print cur.fetchone()[0]
```

### Converting SQLite values to custom Python types

Writing an adapter lets you send custom Python types to SQLite. But to make it really useful we need to make the Python to SQLite to Python roundtrip work.

Enter converters.

Let's go back to the `Point` class. We stored the `x` and `y` coordinates separated via semicolons as strings in SQLite.

First, we'll define a converter function that accepts the string as a parameter and constructs a `Point` object from it.

---

**Note:** Converter functions **always** get called with a string, no matter under which data type you sent the value to SQLite.

---

```
def convert_point(s):
    x, y = map(float, s.split(";"))
    return Point(x, y)
```

Now you need to make the `sqlite3` module know that what you select from the database is actually a point. There are two ways of doing this:

- Implicitly via the declared type
- Explicitly via the column name

Both ways are described in section *Module functions and constants*, in the entries for the constants `PARSE_DECLTYPES` and `PARSE_COLNAMES`.

The following example illustrates both approaches.

```
import sqlite3
```

```

class Point(object):
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __repr__(self):
        return "(%f;%f)" % (self.x, self.y)

def adapt_point(point):
    return "%f;%f" % (point.x, point.y)

def convert_point(s):
    x, y = map(float, s.split(";"))
    return Point(x, y)

# Register the adapter
sqlite3.register_adapter(Point, adapt_point)

# Register the converter
sqlite3.register_converter("point", convert_point)

p = Point(4.0, -3.2)

#####
# 1) Using declared types
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(p point)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute("select p from test")
print "with declared types:", cur.fetchone()[0]
cur.close()
con.close()

#####
# 1) Using column names
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_COLNAMES)
cur = con.cursor()
cur.execute("create table test(p)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute('select p as "p [point]" from test')
print "with column names:", cur.fetchone()[0]
cur.close()
con.close()

```

### Default adapters and converters

There are default adapters for the date and datetime types in the datetime module. They will be sent as ISO dates/ISO timestamps to SQLite.

The default converters are registered under the name “date” for `datetime.date` and under the name “timestamp” for `datetime.datetime`.

This way, you can use date/timestamps from Python without any additional fiddling in most cases. The format of the adapters is also compatible with the experimental SQLite date/time functions.

The following example demonstrates this.

```
import sqlite3
import datetime

con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES|sqlite3.PARSE_COLNAMES)
cur = con.cursor()
cur.execute("create table test(d date, ts timestamp)")

today = datetime.date.today()
now = datetime.datetime.now()

cur.execute("insert into test(d, ts) values (?, ?)", (today, now))
cur.execute("select d, ts from test")
row = cur.fetchone()
print today, "=>", row[0], type(row[0])
print now, "=>", row[1], type(row[1])

cur.execute('select current_date as "d [date]", current_timestamp as "ts [timestamp]"')
row = cur.fetchone()
print "current_date", row[0], type(row[0])
print "current_timestamp", row[1], type(row[1])
```

### 11.13.6 Controlling Transactions

By default, the `sqlite3` module opens transactions implicitly before a Data Modification Language (DML) statement (i.e. `INSERT/UPDATE/DELETE/REPLACE`), and commits transactions implicitly before a non-DML, non-query statement (i. e. anything other than `SELECT` or the aforementioned).

So if you are within a transaction and issue a command like `CREATE TABLE ...`, `VACUUM`, `PRAGMA`, the `sqlite3` module will commit implicitly before executing that command. There are two reasons for doing that. The first is that some of these commands don't work within transactions. The other reason is that `sqlite3` needs to keep track of the transaction state (if a transaction is active or not).

You can control which kind of `BEGIN` statements `sqlite3` implicitly executes (or none at all) via the `isolation_level` parameter to the `connect()` call, or via the `isolation_level` property of connections.

If you want **autocommit mode**, then set `isolation_level` to `None`.

Otherwise leave it at its default, which will result in a plain “`BEGIN`” statement, or set it to one of SQLite's supported isolation levels: “`DEFERRED`”, “`IMMEDIATE`” or “`EXCLUSIVE`”.

### 11.13.7 Using `sqlite3` efficiently

#### Using shortcut methods

Using the nonstandard `execute()`, `executemany()` and `executescript()` methods of the `Connection` object, your code can be written more concisely because you don't have to create the (often superfluous) `Cursor` objects explicitly. Instead, the `Cursor` objects are created implicitly and these shortcut methods return the cursor objects. This way, you can execute a `SELECT` statement and iterate over it directly using only a single call on the `Connection` object.

```

import sqlite3

persons = [
    ("Hugo", "Boss"),
    ("Calvin", "Klein")
]

con = sqlite3.connect(":memory:")

# Create the table
con.execute("create table person(firstname, lastname)")

# Fill the table
con.executemany("insert into person(firstname, lastname) values (?, ?)", persons)

# Print the table contents
for row in con.execute("select firstname, lastname from person"):
    print row

print "I just deleted", con.execute("delete from person").rowcount, "rows"

```

### Accessing columns by name instead of by index

One useful feature of the `sqlite3` module is the built-in `sqlite3.Row` class designed to be used as a row factory. Rows wrapped with this class can be accessed both by index (like tuples) and case-insensitively by name:

```

import sqlite3

con = sqlite3.connect(":memory:")
con.row_factory = sqlite3.Row

cur = con.cursor()
cur.execute("select 'John' as name, 42 as age")
for row in cur:
    assert row[0] == row["name"]
    assert row["name"] == row["nAmE"]
    assert row[1] == row["age"]
    assert row[1] == row["AgE"]

```

### Using the connection as a context manager

New in version 2.6. Connection objects can be used as context managers that automatically commit or rollback transactions. In the event of an exception, the transaction is rolled back; otherwise, the transaction is committed:

```

import sqlite3

con = sqlite3.connect(":memory:")
con.execute("create table person (id integer primary key, firstname varchar unique)")

# Successful, con.commit() is called automatically afterwards
with con:
    con.execute("insert into person(firstname) values (?)", ("Joe",))

```

```
# con.rollback() is called after the with block finishes with an exception, the  
# exception is still raised and must be caught  
try:  
    with con:  
        con.execute("insert into person(firstname) values (?)", ("Joe",))  
except sqlite3.IntegrityError:  
    print "couldn't add Joe twice"
```

### 11.13.8 Common issues

#### Multithreading

Older SQLite versions had issues with sharing connections between threads. That's why the Python module disallows sharing connections and cursors between threads. If you still try to do so, you will get an exception at runtime.

The only exception is calling the `interrupt()` method, which only makes sense to call from a different thread.

# DATA COMPRESSION AND ARCHIVING

The modules described in this chapter support data compression with the `zlib`, `gzip`, and `bzip2` algorithms, and the creation of ZIP- and tar-format archives. See also *Archiving operations* provided by the `shutil` module.

## 12.1 `zlib` — Compression compatible with `gzip`

For applications that require data compression, the functions in this module allow compression and decompression, using the `zlib` library. The `zlib` library has its own home page at <http://www.zlib.net>. There are known incompatibilities between the Python module and versions of the `zlib` library earlier than 1.1.3; 1.1.3 has a security vulnerability, so we recommend using 1.1.4 or later.

`zlib`'s functions have many options and often need to be used in a particular order. This documentation doesn't attempt to cover all of the permutations; consult the `zlib` manual at <http://www.zlib.net/manual.html> for authoritative information.

For reading and writing `.gz` files see the `gzip` module.

The available exception and functions in this module are:

### **exception** `zlib.error`

Exception raised on compression and decompression errors.

### `zlib.adler32` (*data* [, *value* ])

Computes a Adler-32 checksum of *data*. (An Adler-32 checksum is almost as reliable as a CRC32 but can be computed much more quickly.) If *value* is present, it is used as the starting value of the checksum; otherwise, a fixed default value is used. This allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

This function always returns an integer object.

---

**Note:** To generate the same numeric value across all Python versions and platforms use `adler32(data) & 0xffffffff`. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32bit binary representation regardless of sign.

---

Changed in version 2.6: The return value is in the range `[-2**31, 2**31-1]` regardless of platform. In older versions the value is signed on some platforms and unsigned on others. Changed in version 3.0: The return value is unsigned and in the range `[0, 2**32-1]` regardless of platform.

### `zlib.compress` (*string* [, *level* ])

Compresses the data in *string*, returning a string contained compressed data. *level* is an integer from 1 to 9

controlling the level of compression; 1 is fastest and produces the least compression, 9 is slowest and produces the most. The default value is 6. Raises the `error` exception if any error occurs.

`zlib.compressobj([level])`

Returns a compression object, to be used for compressing data streams that won't fit into memory at once. *level* is an integer from 1 to 9 controlling the level of compression; 1 is fastest and produces the least compression, 9 is slowest and produces the most. The default value is 6.

`zlib.crc32(data[, value])`

Computes a CRC (Cyclic Redundancy Check) checksum of *data*. If *value* is present, it is used as the starting value of the checksum; otherwise, a fixed default value is used. This allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

This function always returns an integer object.

---

**Note:** To generate the same numeric value across all Python versions and platforms use `crc32(data) & 0xffffffff`. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32bit binary representation regardless of sign.

---

Changed in version 2.6: The return value is in the range `[-2**31, 2**31-1]` regardless of platform. In older versions the value would be signed on some platforms and unsigned on others. Changed in version 3.0: The return value is unsigned and in the range `[0, 2**32-1]` regardless of platform.

`zlib.decompress(string[, wbits[, bufsize]])`

Decompresses the data in *string*, returning a string containing the uncompressed data. The *wbits* parameter controls the size of the window buffer, and is discussed further below. If *bufsize* is given, it is used as the initial size of the output buffer. Raises the `error` exception if any error occurs.

The absolute value of *wbits* is the base two logarithm of the size of the history buffer (the “window size”) used when compressing data. Its absolute value should be between 8 and 15 for the most recent versions of the `zlib` library, larger values resulting in better compression at the expense of greater memory usage. When decompressing a stream, *wbits* must not be smaller than the size originally used to compress the stream; using a too-small value will result in an exception. The default value is therefore the highest value, 15. When *wbits* is negative, the standard **gzip** header is suppressed.

*bufsize* is the initial size of the buffer used to hold decompressed data. If more space is required, the buffer size will be increased as needed, so you don't have to get this value exactly right; tuning it will only save a few calls to `malloc()`. The default size is 16384.

`zlib.decompressobj([wbits])`

Returns a decompression object, to be used for decompressing data streams that won't fit into memory at once. The *wbits* parameter controls the size of the window buffer.

Compression objects support the following methods:

`Compress.compress(string)`

Compress *string*, returning a string containing compressed data for at least part of the data in *string*. This data should be concatenated to the output produced by any preceding calls to the `compress()` method. Some input may be kept in internal buffers for later processing.

`Compress.flush([mode])`

All pending input is processed, and a string containing the remaining compressed output is returned. *mode* can be selected from the constants `Z_SYNC_FLUSH`, `Z_FULL_FLUSH`, or `Z_FINISH`, defaulting to `Z_FINISH`. `Z_SYNC_FLUSH` and `Z_FULL_FLUSH` allow compressing further strings of data, while `Z_FINISH` finishes the compressed stream and prevents compressing any more data. After calling `flush()` with *mode* set to `Z_FINISH`, the `compress()` method cannot be called again; the only realistic action is to delete the object.

`Compress.copy()`

Returns a copy of the compression object. This can be used to efficiently compress a set of data that share a common initial prefix. New in version 2.5.

Decompression objects support the following methods, and two attributes:

`Decompress.unused_data`

A string which contains any bytes past the end of the compressed data. That is, this remains "" until the last byte that contains compression data is available. If the whole string turned out to contain compressed data, this is "", the empty string.

The only way to determine where a string of compressed data ends is by actually decompressing it. This means that when compressed data is contained part of a larger file, you can only find the end of it by reading data and feeding it followed by some non-empty string into a decompression object's `decompress()` method until the `unused_data` attribute is no longer the empty string.

`Decompress.unconsumed_tail`

A string that contains any data that was not consumed by the last `decompress()` call because it exceeded the limit for the uncompressed data buffer. This data has not yet been seen by the zlib machinery, so you must feed it (possibly with further data concatenated to it) back to a subsequent `decompress()` method call in order to get correct output.

`Decompress.decompress(string[, max_length])`

Decompress *string*, returning a string containing the uncompressed data corresponding to at least part of the data in *string*. This data should be concatenated to the output produced by any preceding calls to the `decompress()` method. Some of the input data may be preserved in internal buffers for later processing.

If the optional parameter *max\_length* is supplied then the return value will be no longer than *max\_length*. This may mean that not all of the compressed input can be processed; and unconsumed data will be stored in the attribute `unconsumed_tail`. This string must be passed to a subsequent call to `decompress()` if decompression is to continue. If *max\_length* is not supplied then the whole input is decompressed, and `unconsumed_tail` is an empty string.

`Decompress.flush([length])`

All pending input is processed, and a string containing the remaining uncompressed output is returned. After calling `flush()`, the `decompress()` method cannot be called again; the only realistic action is to delete the object.

The optional parameter *length* sets the initial size of the output buffer.

`Decompress.copy()`

Returns a copy of the decompression object. This can be used to save the state of the decompressor midway through the data stream in order to speed up random seeks into the stream at a future point. New in version 2.5.

**See Also:**

**Module `gzip`** Reading and writing `gzip`-format files.

<http://www.zlib.net> The zlib library home page.

<http://www.zlib.net/manual.html> The zlib manual explains the semantics and usage of the library's many functions.

## 12.2 `gzip` — Support for `gzip` files

**Source code:** `Lib/gzip.py`

This module provides a simple interface to compress and decompress files just like the GNU programs `gzip` and `gunzip` would.

The data compression is provided by the `zlib` module.

The `gzip` module provides the `GzipFile` class which is modeled after Python's File Object. The `GzipFile` class reads and writes **gzip**-format files, automatically compressing or decompressing the data so that it looks like an ordinary file object.

Note that additional file formats which can be decompressed by the **gzip** and **gunzip** programs, such as those produced by **compress** and **pack**, are not supported by this module.

The module defines the following items:

**class** `gzip.GzipFile` (`[filename[, mode[, compresslevel[, fileobj[, mtime ]]]]`)

Constructor for the `GzipFile` class, which simulates most of the methods of a file object, with the exception of the `readinto()` and `truncate()` methods. At least one of `fileobj` and `filename` must be given a non-trivial value.

The new class instance is based on `fileobj`, which can be a regular file, a `StringIO` object, or any other object which simulates a file. It defaults to `None`, in which case `filename` is opened to provide a file object.

When `fileobj` is not `None`, the `filename` argument is only used to be included in the **gzip** file header, which may include the original filename of the uncompressed file. It defaults to the filename of `fileobj`, if discernible; otherwise, it defaults to the empty string, and in this case the original filename is not included in the header.

The `mode` argument can be any of `'r'`, `'rb'`, `'a'`, `'ab'`, `'w'`, or `'wb'`, depending on whether the file will be read or written. The default is the mode of `fileobj` if discernible; otherwise, the default is `'rb'`. If not given, the `'b'` flag will be added to the mode to ensure the file is opened in binary mode for cross-platform portability.

The `compresslevel` argument is an integer from 1 to 9 controlling the level of compression; 1 is fastest and produces the least compression, and 9 is slowest and produces the most compression. The default is 9.

The `mtime` argument is an optional numeric timestamp to be written to the stream when compressing. All **gzip** compressed streams are required to contain a timestamp. If omitted or `None`, the current time is used. This module ignores the timestamp when decompressing; however, some programs, such as **gunzip**, make use of it. The format of the timestamp is the same as that of the return value of `time.time()` and of the `st_mtime` attribute of the object returned by `os.stat()`.

Calling a `GzipFile` object's `close()` method does not close `fileobj`, since you might wish to append more material after the compressed data. This also allows you to pass a `StringIO` object opened for writing as `fileobj`, and retrieve the resulting memory buffer using the `StringIO` object's `getvalue()` method.

`GzipFile` supports iteration and the `with` statement. Changed in version 2.7: Support for the `with` statement was added. Changed in version 2.7: Support for zero-padded files was added.

`gzip.open` (`filename[, mode[, compresslevel ]]`)

This is a shorthand for `GzipFile(filename, mode, compresslevel)`. The `filename` argument is required; `mode` defaults to `'rb'` and `compresslevel` defaults to 9.

### 12.2.1 Examples of usage

Example of how to read a compressed file:

```
import gzip
f = gzip.open('/home/joe/file.txt.gz', 'rb')
file_content = f.read()
f.close()
```

Example of how to create a compressed GZIP file:

```
import gzip
content = "Lots of content here"
f = gzip.open('/home/joe/file.txt.gz', 'wb')
```

```
f.write(content)
f.close()
```

Example of how to GZIP compress an existing file:

```
import gzip
f_in = open('/home/joe/file.txt', 'rb')
f_out = gzip.open('/home/joe/file.txt.gz', 'wb')
f_out.writelines(f_in)
f_out.close()
f_in.close()
```

**See Also:**

**Module `zlib`** The basic data compression module needed to support the `gzip` file format.

## 12.3 bz2 — Compression compatible with bzip2

New in version 2.3. This module provides a comprehensive interface for the bz2 compression library. It implements a complete file interface, one-shot (de)compression functions, and types for sequential (de)compression.

Here is a summary of the features offered by the bz2 module:

- `BZ2File` class implements a complete file interface, including `readline()`, `readlines()`, `writelines()`, `seek()`, etc;
- `BZ2File` class implements emulated `seek()` support;
- `BZ2File` class implements universal newline support;
- `BZ2File` class offers an optimized line iteration using the readahead algorithm borrowed from file objects;
- Sequential (de)compression supported by `BZ2Compressor` and `BZ2Decompressor` classes;
- One-shot (de)compression supported by `compress()` and `decompress()` functions;
- Thread safety uses individual locking mechanism.

### 12.3.1 (De)compression of files

Handling of compressed files is offered by the `BZ2File` class.

**class** `bz2.BZ2File` (*filename*[, *mode*[, *buffering*[, *compresslevel*]]])

Open a bz2 file. Mode can be either `'r'` or `'w'`, for reading (default) or writing. When opened for writing, the file will be created if it doesn't exist, and truncated otherwise. If *buffering* is given, 0 means unbuffered, and larger numbers specify the buffer size; the default is 0. If *compresslevel* is given, it must be a number between 1 and 9; the default is 9. Add a `'U'` to mode to open the file for input in *universal newlines* mode. Any line ending in the input file will be seen as a `'\n'` in Python. Also, a file so opened gains the attribute `newlines`; the value for this attribute is one of `None` (no newline read yet), `'\r'`, `'\n'`, `'\r\n'` or a tuple containing all the newline types seen. Universal newlines are available only when reading. Instances support iteration in the same way as normal `file` instances.

`BZ2File` supports the `with` statement. Changed in version 2.7: Support for the `with` statement was added.

**Note:** This class does not support input files containing multiple streams (such as those produced by the `pbzip2` tool). When reading such an input file, only the first stream will be accessible. If you require support for multi-stream files, consider using the third-party `bz2file` module (available from `PyPI`). This module provides a backport of Python 3.3's `BZ2File` class, which does support multi-stream files.

**close()**

Close the file. Sets data attribute `closed` to true. A closed file cannot be used for further I/O operations. `close()` may be called more than once without error.

**read([size])**

Read at most *size* uncompressed bytes, returned as a string. If the *size* argument is negative or omitted, read until EOF is reached.

**readline([size])**

Return the next line from the file, as a string, retaining newline. A non-negative *size* argument limits the maximum number of bytes to return (an incomplete line may be returned then). Return an empty string at EOF.

**readlines([size])**

Return a list of lines read. The optional *size* argument, if given, is an approximate bound on the total number of bytes in the lines returned.

**xreadlines()**

For backward compatibility. `BZ2File` objects now include the performance optimizations previously implemented in the `xreadlines` module. Deprecated since version 2.3: This exists only for compatibility with the method by this name on `file` objects, which is deprecated. Use `for line in file` instead.

**seek(offset[, whence])**

Move to new file position. Argument *offset* is a byte count. Optional argument *whence* defaults to `os.SEEK_SET` or 0 (offset from start of file; offset should be  $\geq 0$ ); other values are `os.SEEK_CUR` or 1 (move relative to current position; offset can be positive or negative), and `os.SEEK_END` or 2 (move relative to end of file; offset is usually negative, although many platforms allow seeking beyond the end of a file).

Note that seeking of bz2 files is emulated, and depending on the parameters the operation may be extremely slow.

**tell()**

Return the current file position, an integer (may be a long integer).

**write(data)**

Write string *data* to file. Note that due to buffering, `close()` may be needed before the file on disk reflects the data written.

**writelines(sequence\_of\_strings)**

Write the sequence of strings to the file. Note that newlines are not added. The sequence can be any iterable object producing strings. This is equivalent to calling `write()` for each string.

## 12.3.2 Sequential (de)compression

Sequential compression and decompression is done using the classes `BZ2Compressor` and `BZ2Decompressor`.

**class bz2.BZ2Compressor([compresslevel])**

Create a new compressor object. This object may be used to compress data sequentially. If you want to compress data in one shot, use the `compress()` function instead. The *compresslevel* parameter, if given, must be a number between 1 and 9; the default is 9.

**compress(data)**

Provide more data to the compressor object. It will return chunks of compressed data whenever possible. When you've finished providing data to compress, call the `flush()` method to finish the compression process, and return what is left in internal buffers.

**flush()**

Finish the compression process and return what is left in internal buffers. You must not use the compressor object after calling this method.

**class bz2.BZ2Decompressor**

Create a new decompressor object. This object may be used to decompress data sequentially. If you want to decompress data in one shot, use the `decompress()` function instead.

**decompress(data)**

Provide more data to the decompressor object. It will return chunks of decompressed data whenever possible. If you try to decompress data after the end of stream is found, `EOFError` will be raised. If any data was found after the end of stream, it'll be ignored and saved in `unused_data` attribute.

### 12.3.3 One-shot (de)compression

One-shot compression and decompression is provided through the `compress()` and `decompress()` functions.

**bz2.compress(data[, compresslevel])**

Compress *data* in one shot. If you want to compress data sequentially, use an instance of `BZ2Compressor` instead. The *compresslevel* parameter, if given, must be a number between 1 and 9; the default is 9.

**bz2.decompress(data)**

Decompress *data* in one shot. If you want to decompress data sequentially, use an instance of `BZ2Decompressor` instead.

## 12.4 zipfile — Work with ZIP archives

New in version 1.6. **Source code:** [Lib/zipfile.py](#)

The ZIP file format is a common archive and compression standard. This module provides tools to create, read, write, append, and list a ZIP file. Any advanced use of this module will require an understanding of the format, as defined in [PKZIP Application Note](#).

This module does not currently handle multi-disk ZIP files. It can handle ZIP files that use the ZIP64 extensions (that is ZIP files that are more than 4 GByte in size). It supports decryption of encrypted files in ZIP archives, but it currently cannot create an encrypted file. Decryption is extremely slow as it is implemented in native Python rather than C.

The module defines the following items:

**exception zipfile.BadZipfile**

The error raised for bad ZIP files (old name: `zipfile.error`).

**exception zipfile.LargeZipFile**

The error raised when a ZIP file would require ZIP64 functionality but that has not been enabled.

**class zipfile.ZipFile**

The class for reading and writing ZIP files. See section [ZipFile Objects](#) for constructor details.

**class zipfile.PyZipFile**

Class for creating ZIP archives containing Python libraries.

**class zipfile.ZipInfo([filename[, date\_time]])**

Class used to represent information about a member of an archive. Instances of this class are returned by the `getinfo()` and `infolist()` methods of `ZipFile` objects. Most users of the `zipfile` module will not need to create these, but only use those created by this module. *filename* should be the full name of the archive

member, and *date\_time* should be a tuple containing six fields which describe the time of the last modification to the file; the fields are described in section *ZipInfo Objects*.

`zipfile.is_zipfile(filename)`

Returns `True` if *filename* is a valid ZIP file based on its magic number, otherwise returns `False`. *filename* may be a file or file-like object too. Changed in version 2.7: Support for file and file-like objects.

`zipfile.ZIP_STORED`

The numeric constant for an uncompressed archive member.

`zipfile.ZIP_DEFLATED`

The numeric constant for the usual ZIP compression method. This requires the `zlib` module. No other compression methods are currently supported.

**See Also:**

**PKZIP Application Note** Documentation on the ZIP file format by Phil Katz, the creator of the format and algorithms used.

**Info-ZIP Home Page** Information about the Info-ZIP project's ZIP archive programs and development libraries.

## 12.4.1 ZipFile Objects

**class** `zipfile.ZipFile(file[, mode[, compression[, allowZip64 ] ] ])`

Open a ZIP file, where *file* can be either a path to a file (a string) or a file-like object. The *mode* parameter should be `'r'` to read an existing file, `'w'` to truncate and write a new file, or `'a'` to append to an existing file. If *mode* is `'a'` and *file* refers to an existing ZIP file, then additional files are added to it. If *file* does not refer to a ZIP file, then a new ZIP archive is appended to the file. This is meant for adding a ZIP archive to another file (such as `python.exe`). Changed in version 2.6: If *mode* is `a` and the file does not exist at all, it is created. *compression* is the ZIP compression method to use when writing the archive, and should be `ZIP_STORED` or `ZIP_DEFLATED`; unrecognized values will cause `RuntimeError` to be raised. If `ZIP_DEFLATED` is specified but the `zlib` module is not available, `RuntimeError` is also raised. The default is `ZIP_STORED`. If *allowZip64* is `True` `zipfile` will create ZIP files that use the ZIP64 extensions when the zipfile is larger than 2 GB. If it is `false` (the default) `zipfile` will raise an exception when the ZIP file would require ZIP64 extensions. ZIP64 extensions are disabled by default because the default `zip` and `unzip` commands on Unix (the InfoZIP utilities) don't support these extensions. Changed in version 2.7.1: If the file is created with mode `'a'` or `'w'` and then `close()`d without adding any files to the archive, the appropriate ZIP structures for an empty archive will be written to the file. `ZipFile` is also a context manager and therefore supports the `with` statement. In the example, *myzip* is closed after the `with` statement's suite is finished—even if an exception occurs:

```
with ZipFile('spam.zip', 'w') as myzip:
    myzip.write('eggs.txt')
```

New in version 2.7: Added the ability to use `ZipFile` as a context manager.

`ZipFile.close()`

Close the archive file. You must call `close()` before exiting your program or essential records will not be written.

`ZipFile.getinfo(name)`

Return a `ZipInfo` object with information about the archive member *name*. Calling `getinfo()` for a name not currently contained in the archive will raise a `KeyError`.

`ZipFile.infolist()`

Return a list containing a `ZipInfo` object for each member of the archive. The objects are in the same order as their entries in the actual ZIP file on disk if an existing archive was opened.

`ZipFile.namelist()`

Return a list of archive members by name.

`ZipFile.open(name[, mode[, pwd]])`

Extract a member from the archive as a file-like object (`ZipExtFile`). *name* is the name of the file in the archive, or a `ZipInfo` object. The *mode* parameter, if included, must be one of the following: `'r'` (the default), `'U'`, or `'rU'`. Choosing `'U'` or `'rU'` will enable *universal newline* support in the read-only object. *pwd* is the password used for encrypted files. Calling `open()` on a closed `ZipFile` will raise a `RuntimeError`.

---

**Note:** The file-like object is read-only and provides the following methods: `read()`, `readline()`, `readlines()`, `__iter__()`, `next()`.

---

**Note:** If the `ZipFile` was created by passing in a file-like object as the first argument to the constructor, then the object returned by `open()` shares the `ZipFile`'s file pointer. Under these circumstances, the object returned by `open()` should not be used after any additional operations are performed on the `ZipFile` object. If the `ZipFile` was created by passing in a string (the filename) as the first argument to the constructor, then `open()` will create a new file object that will be held by the `ZipExtFile`, allowing it to operate independently of the `ZipFile`.

---

**Note:** The `open()`, `read()` and `extract()` methods can take a filename or a `ZipInfo` object. You will appreciate this when trying to read a ZIP file that contains members with duplicate names.

---

New in version 2.6.

`ZipFile.extract(member[, path[, pwd]])`

Extract a member from the archive to the current working directory; *member* must be its full name or a `ZipInfo` object). Its file information is extracted as accurately as possible. *path* specifies a different directory to extract to. *member* can be a filename or a `ZipInfo` object. *pwd* is the password used for encrypted files. New in version 2.6.

`ZipFile.extractall([path[, members[, pwd]])`

Extract all members from the archive to the current working directory. *path* specifies a different directory to extract to. *members* is optional and must be a subset of the list returned by `namelist()`. *pwd* is the password used for encrypted files.

**Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of *path*, e.g. members that have absolute filenames starting with `"/"` or filenames with two dots `".."`.

New in version 2.6.

`ZipFile.printdir()`

Print a table of contents for the archive to `sys.stdout`.

`ZipFile.setpassword(pwd)`

Set *pwd* as default password to extract encrypted files. New in version 2.6.

`ZipFile.read(name[, pwd])`

Return the bytes of the file *name* in the archive. *name* is the name of the file in the archive, or a `ZipInfo` object. The archive must be open for read or append. *pwd* is the password used for encrypted files and, if specified, it will override the default password set with `setpassword()`. Calling `read()` on a closed `ZipFile` will raise a `RuntimeError`. Changed in version 2.6: *pwd* was added, and *name* can now be a `ZipInfo` object.

`ZipFile.testzip()`

Read all the files in the archive and check their CRC's and file headers. Return the name of the first bad file, or else return `None`. Calling `testzip()` on a closed `ZipFile` will raise a `RuntimeError`.

`ZipFile.write(filename[, arcname[, compress_type ]])`

Write the file named *filename* to the archive, giving it the archive name *arcname* (by default, this will be the same as *filename*, but without a drive letter and with leading path separators removed). If given, *compress\_type* overrides the value given for the *compression* parameter to the constructor for the new entry. The archive must be open with mode 'w' or 'a' – calling `write()` on a `ZipFile` created with mode 'r' will raise a `RuntimeError`. Calling `write()` on a closed `ZipFile` will raise a `RuntimeError`.

---

**Note:** There is no official file name encoding for ZIP files. If you have unicode file names, you must convert them to byte strings in your desired encoding before passing them to `write()`. WinZip interprets all file names as encoded in CP437, also known as DOS Latin.

---

---

**Note:** Archive names should be relative to the archive root, that is, they should not start with a path separator.

---

---

**Note:** If *arcname* (or *filename*, if *arcname* is not given) contains a null byte, the name of the file in the archive will be truncated at the null byte.

---

`ZipFile.writestr(zinfo_or_arcname, bytes[, compress_type ])`

Write the string *bytes* to the archive; *zinfo\_or\_arcname* is either the file name it will be given in the archive, or a `ZipInfo` instance. If it's an instance, at least the filename, date, and time must be given. If it's a name, the date and time is set to the current date and time. The archive must be opened with mode 'w' or 'a' – calling `writestr()` on a `ZipFile` created with mode 'r' will raise a `RuntimeError`. Calling `writestr()` on a closed `ZipFile` will raise a `RuntimeError`.

If given, *compress\_type* overrides the value given for the *compression* parameter to the constructor for the new entry, or in the *zinfo\_or\_arcname* (if that is a `ZipInfo` instance).

---

**Note:** When passing a `ZipInfo` instance as the *zinfo\_or\_arcname* parameter, the compression method used will be that specified in the *compress\_type* member of the given `ZipInfo` instance. By default, the `ZipInfo` constructor sets this member to `ZIP_STORED`.

---

Changed in version 2.7: The *compression\_type* argument.

The following data attributes are also available:

`ZipFile.debug`

The level of debug output to use. This may be set from 0 (the default, no output) to 3 (the most output). Debugging information is written to `sys.stdout`.

`ZipFile.comment`

The comment text associated with the ZIP file. If assigning a comment to a `ZipFile` instance created with mode 'a' or 'w', this should be a string no longer than 65535 bytes. Comments longer than this will be truncated in the written archive when `ZipFile.close()` is called.

## 12.4.2 PyZipFile Objects

The `PyZipFile` constructor takes the same parameters as the `ZipFile` constructor. Instances have one method in addition to those of `ZipFile` objects.

`PyZipFile.writepy(pathname[, basename ])`

Search for files `*.py` and add the corresponding file to the archive. The corresponding file is a `*.pyo` file if available, else a `*.pyc` file, compiling if necessary. If the *pathname* is a file, the filename must end with `.py`, and just the (corresponding `*.py[co]`) file is added at the top level (no path information). If the *pathname* is a

file that does not end with `.py`, a `RuntimeError` will be raised. If it is a directory, and the directory is not a package directory, then all the files `*.py[co]` are added at the top level. If the directory is a package directory, then all `*.py[co]` are added under the package name as a file path, and if any subdirectories are package directories, all of these are added recursively. `basename` is intended for internal use only. The `writetpy()` method makes archives with file names like this:

```
string.pyc                # Top level name
test/__init__.pyc        # Package directory
test/test_support.pyc    # Module test.test_support
test/bogus/__init__.pyc  # Subpackage directory
test/bogus/myfile.pyc    # Submodule test.bogus.myfile
```

### 12.4.3 ZipInfo Objects

Instances of the `ZipInfo` class are returned by the `getinfo()` and `infolist()` methods of `ZipFile` objects. Each object stores information about a single member of the ZIP archive.

Instances have the following attributes:

**ZipInfo.filename**

Name of the file in the archive.

**ZipInfo.date\_time**

The time and date of the last modification to the archive member. This is a tuple of six values:

Index	Value
0	Year ( $\geq 1980$ )
1	Month (one-based)
2	Day of month (one-based)
3	Hours (zero-based)
4	Minutes (zero-based)
5	Seconds (zero-based)

**Note:** The ZIP file format does not support timestamps before 1980.

**ZipInfo.compress\_type**

Type of compression for the archive member.

**ZipInfo.comment**

Comment for the individual archive member.

**ZipInfo.extra**

Expansion field data. The [PKZIP Application Note](#) contains some comments on the internal structure of the data contained in this string.

**ZipInfo.create\_system**

System which created ZIP archive.

**ZipInfo.create\_version**

PKZIP version which created ZIP archive.

**ZipInfo.extract\_version**

PKZIP version needed to extract archive.

**ZipInfo.reserved**

Must be zero.

`ZipInfo.flag_bits`

ZIP flag bits.

`ZipInfo.volume`

Volume number of file header.

`ZipInfo.internal_attr`

Internal attributes.

`ZipInfo.external_attr`

External file attributes.

`ZipInfo.header_offset`

Byte offset to the file header.

`ZipInfo.CRC`

CRC-32 of the uncompressed file.

`ZipInfo.compress_size`

Size of the compressed data.

`ZipInfo.file_size`

Size of the uncompressed file.

## 12.5 tarfile — Read and write tar archive files

New in version 2.3. **Source code:** [Lib/tarfile.py](#)

---

The `tarfile` module makes it possible to read and write tar archives, including those using `gzip` or `bz2` compression. Use the `zipfile` module to read or write `.zip` files, or the higher-level functions in `shutil`.

Some facts and figures:

- reads and writes `gzip` and `bz2` compressed archives.
- read/write support for the POSIX.1-1988 (ustar) format.
- read/write support for the GNU tar format including *longname* and *longlink* extensions, read-only support for the *sparse* extension.
- read/write support for the POSIX.1-2001 (pax) format. New in version 2.6.
- handles directories, regular files, hardlinks, symbolic links, fifos, character devices and block devices and is able to acquire and restore file information like timestamp, access permissions and owner.

`tarfile.open` (*name=None, mode='r', fileobj=None, bufsize=10240, \*\*kwargs*)

Return a `TarFile` object for the pathname *name*. For detailed information on `TarFile` objects and the keyword arguments that are allowed, see *TarFile Objects*.

*mode* has to be a string of the form `'filemode[:compression]'`, it defaults to `'r'`. Here is a full list of mode combinations:

mode	action
'r' or 'r:*'	Open for reading with transparent compression (recommended).
'r:'	Open for reading exclusively without compression.
'r:gz'	Open for reading with gzip compression.
'r:bz2'	Open for reading with bzip2 compression.
'a' or 'a:'	Open for appending with no compression. The file is created if it does not exist.
'w' or 'w:'	Open for uncompressed writing.
'w:gz'	Open for gzip compressed writing.
'w:bz2'	Open for bzip2 compressed writing.

Note that 'a:gz' or 'a:bz2' is not possible. If *mode* is not suitable to open a certain (compressed) file for reading, `ReadError` is raised. Use *mode* 'r' to avoid this. If a compression method is not supported, `CompressionError` is raised.

If *fileobj* is specified, it is used as an alternative to a file object opened for *name*. It is supposed to be at position 0.

For special purposes, there is a second format for *mode*: 'filemode|[compression]'. `tarfile.open()` will return a `TarFile` object that processes its data as a stream of blocks. No random seeking will be done on the file. If given, *fileobj* may be any object that has a `read()` or `write()` method (depending on the *mode*). *bufsize* specifies the blocksize and defaults to  $20 * 512$  bytes. Use this variant in combination with e.g. `sys.stdin`, a socket file object or a tape device. However, such a `TarFile` object is limited in that it does not allow to be accessed randomly, see *Examples*. The currently possible modes:

Mode	Action
'r *'	Open a <i>stream</i> of tar blocks for reading with transparent compression.
'r '	Open a <i>stream</i> of uncompressed tar blocks for reading.
'r gz'	Open a gzip compressed <i>stream</i> for reading.
'r bz2'	Open a bzip2 compressed <i>stream</i> for reading.
'w '	Open an uncompressed <i>stream</i> for writing.
'w gz'	Open an gzip compressed <i>stream</i> for writing.
'w bz2'	Open an bzip2 compressed <i>stream</i> for writing.

#### class `tarfile.TarFile`

Class for reading and writing tar archives. Do not use this class directly, better use `tarfile.open()` instead. See *TarFile Objects*.

#### `tarfile.is_tarfile` (*name*)

Return `True` if *name* is a tar archive file, that the `tarfile` module can read.

#### class `tarfile.TarFileCompat` (*filename*, *mode*='r', *compression*=`TAR_PLAIN`)

Class for limited access to tar archives with a `zipfile`-like interface. Please consult the documentation of the `zipfile` module for more details. *compression* must be one of the following constants:

##### `TAR_PLAIN`

Constant for an uncompressed tar archive.

##### `TAR_GZIPPED`

Constant for a `gzip` compressed tar archive.

Deprecated since version 2.6: The `TarFileCompat` class has been removed in Python 3.

#### exception `tarfile.TarError`

Base class for all `tarfile` exceptions.

#### exception `tarfile.ReadError`

Is raised when a tar archive is opened, that either cannot be handled by the `tarfile` module or is somehow invalid.

**exception** `tarfile.CompressionError`

Is raised when a compression method is not supported or when the data cannot be decoded properly.

**exception** `tarfile.StreamError`

Is raised for the limitations that are typical for stream-like `TarFile` objects.

**exception** `tarfile.ExtractError`

Is raised for *non-fatal* errors when using `TarFile.extract()`, but only if `TarFile.errorlevel==2`.

**exception** `tarfile.HeaderError`

Is raised by `TarInfo.frombuf()` if the buffer it gets is invalid. New in version 2.6.

Each of the following constants defines a tar archive format that the `tarfile` module is able to create. See section *Supported tar formats* for details.

`tarfile.USTAR_FORMAT`

POSIX.1-1988 (ustar) format.

`tarfile.GNU_FORMAT`

GNU tar format.

`tarfile.PAX_FORMAT`

POSIX.1-2001 (pax) format.

`tarfile.DEFAULT_FORMAT`

The default format for creating archives. This is currently `GNU_FORMAT`.

The following variables are available on module level:

`tarfile.ENCODING`

The default character encoding i.e. the value from either `sys.getfilesystemencoding()` or `sys.getdefaultencoding()`.

**See Also:**

**Module** `zipfile` Documentation of the `zipfile` standard module.

**GNU tar manual, Basic Tar Format** Documentation for tar archive files, including GNU tar extensions.

## 12.5.1 TarFile Objects

The `TarFile` object provides an interface to a tar archive. A tar archive is a sequence of blocks. An archive member (a stored file) is made up of a header block followed by data blocks. It is possible to store a file in a tar archive several times. Each archive member is represented by a `TarInfo` object, see *TarInfo Objects* for details.

A `TarFile` object can be used as a context manager in a `with` statement. It will automatically be closed when the block is completed. Please note that in the event of an exception an archive opened for writing will not be finalized; only the internally used file object will be closed. See the *Examples* section for a use case. New in version 2.7: Added support for the context manager protocol.

```
class tarfile.TarFile (name=None, mode='r', fileobj=None, format=DEFAULT_FORMAT, tar-
                    info=TarInfo, dereference=False, ignore_zeros=False, encoding=ENCODING,
                    errors=None, pax_headers=None, debug=0, errorlevel=0)
```

All following arguments are optional and can be accessed as instance attributes as well.

*name* is the pathname of the archive. It can be omitted if *fileobj* is given. In this case, the file object's name attribute is used if it exists.

*mode* is either 'r' to read from an existing archive, 'a' to append data to an existing file or 'w' to create a new file overwriting an existing one.

If *fileobj* is given, it is used for reading or writing data. If it can be determined, *mode* is overridden by *fileobj*'s mode. *fileobj* will be used from position 0.

---

**Note:** *fileobj* is not closed, when `TarFile` is closed.

---

*format* controls the archive format. It must be one of the constants `USTAR_FORMAT`, `GNU_FORMAT` or `PAX_FORMAT` that are defined at module level. New in version 2.6. The *tarinfo* argument can be used to replace the default `TarInfo` class with a different one. New in version 2.6. If *dereference* is `False`, add symbolic and hard links to the archive. If it is `True`, add the content of the target files to the archive. This has no effect on systems that do not support symbolic links.

If *ignore\_zeros* is `False`, treat an empty block as the end of the archive. If it is `True`, skip empty (and invalid) blocks and try to get as many members as possible. This is only useful for reading concatenated or damaged archives.

*debug* can be set from 0 (no debug messages) up to 3 (all debug messages). The messages are written to `sys.stderr`.

If *errorlevel* is 0, all errors are ignored when using `TarFile.extract()`. Nevertheless, they appear as error messages in the debug output, when debugging is enabled. If 1, all *fatal* errors are raised as `OSError` or `IOError` exceptions. If 2, all *non-fatal* errors are raised as `TarError` exceptions as well.

The *encoding* and *errors* arguments control the way strings are converted to unicode objects and vice versa. The default settings will work for most users. See section *Unicode issues* for in-depth information. New in version 2.6. The *pax\_headers* argument is an optional dictionary of unicode strings which will be added as a pax global header if *format* is `PAX_FORMAT`. New in version 2.6.

`TarFile.open(...)`

Alternative constructor. The `tarfile.open()` function is actually a shortcut to this classmethod.

`TarFile.getmember(name)`

Return a `TarInfo` object for member *name*. If *name* can not be found in the archive, `KeyError` is raised.

---

**Note:** If a member occurs more than once in the archive, its last occurrence is assumed to be the most up-to-date version.

---

`TarFile.getmembers()`

Return the members of the archive as a list of `TarInfo` objects. The list has the same order as the members in the archive.

`TarFile.getnames()`

Return the members as a list of their names. It has the same order as the list returned by `getmembers()`.

`TarFile.list(verbose=True)`

Print a table of contents to `sys.stdout`. If *verbose* is `False`, only the names of the members are printed. If it is `True`, output similar to that of `ls -l` is produced.

`TarFile.next()`

Return the next member of the archive as a `TarInfo` object, when `TarFile` is opened for reading. Return `None` if there is no more available.

`TarFile.extractall(path=".", members=None)`

Extract all members from the archive to the current working directory or directory *path*. If optional *members* is given, it must be a subset of the list returned by `getmembers()`. Directory information like owner, modification time and permissions are set after all members have been extracted. This is done to work around two problems: A directory's modification time is reset each time a file is created in it. And, if a directory's permissions do not allow writing, extracting files to it will fail.

**Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of *path*, e.g. members that have absolute filenames starting with "/" or filenames with two dots ".".

New in version 2.5.

`TarFile.extract` (*member*, *path=""*)

Extract a member from the archive to the current working directory, using its full name. Its file information is extracted as accurately as possible. *member* may be a filename or a `TarInfo` object. You can specify a different directory using *path*.

---

**Note:** The `extract()` method does not take care of several extraction issues. In most cases you should consider using the `extractall()` method.

**Warning:** See the warning for `extractall()`.

`TarFile.extractfile` (*member*)

Extract a member from the archive as a file object. *member* may be a filename or a `TarInfo` object. If *member* is a regular file, a file-like object is returned. If *member* is a link, a file-like object is constructed from the link's target. If *member* is none of the above, `None` is returned.

---

**Note:** The file-like object is read-only. It provides the methods `read()`, `readline()`, `readlines()`, `seek()`, `tell()`, and `close()`, and also supports iteration over its lines.

`TarFile.add` (*name*, *arcname=None*, *recursive=True*, *exclude=None*, *filter=None*)

Add the file *name* to the archive. *name* may be any type of file (directory, fifo, symbolic link, etc.). If given, *arcname* specifies an alternative name for the file in the archive. Directories are added recursively by default. This can be avoided by setting *recursive* to `False`. If *exclude* is given it must be a function that takes one filename argument and returns a boolean value. Depending on this value the respective file is either excluded (`True`) or added (`False`). If *filter* is specified it must be a function that takes a `TarInfo` object argument and returns the changed `TarInfo` object. If it instead returns `None` the `TarInfo` object will be excluded from the archive. See *Examples* for an example. Changed in version 2.6: Added the *exclude* parameter. Changed in version 2.7: Added the *filter* parameter. Deprecated since version 2.7: The *exclude* parameter is deprecated, please use the *filter* parameter instead. For maximum portability, *filter* should be used as a keyword argument rather than as a positional argument so that code won't be affected when *exclude* is ultimately removed.

`TarFile.addfile` (*tarinfo*, *fileobj=None*)

Add the `TarInfo` object *tarinfo* to the archive. If *fileobj* is given, *tarinfo.size* bytes are read from it and added to the archive. You can create `TarInfo` objects using `gettinfo()`.

---

**Note:** On Windows platforms, *fileobj* should always be opened with mode 'rb' to avoid irritation about the file size.

`TarFile.gettarinfo` (*name=None*, *arcname=None*, *fileobj=None*)

Create a `TarInfo` object for either the file *name* or the file object *fileobj* (using `os.fstat()` on its file descriptor). You can modify some of the `TarInfo`'s attributes before you add it using `addfile()`. If given, *arcname* specifies an alternative name for the file in the archive.

`TarFile.close` ()

Close the `TarFile`. In write mode, two finishing zero blocks are appended to the archive.

`TarFile.posix`

Setting this to `True` is equivalent to setting the *format* attribute to `USTAR_FORMAT`, `False` is equivalent

to `GNU_FORMAT`. Changed in version 2.4: `posix` defaults to `False`. Deprecated since version 2.6: Use the `format` attribute instead.

#### `TarFile.pax_headers`

A dictionary containing key-value pairs of pax global headers. New in version 2.6.

## 12.5.2 TarInfo Objects

A `TarInfo` object represents one member in a `TarFile`. Aside from storing all required attributes of a file (like file type, size, time, permissions, owner etc.), it provides some useful methods to determine its type. It does *not* contain the file's data itself.

`TarInfo` objects are returned by `TarFile`'s methods `getmember()`, `getmembers()` and `gettartinfo()`.

**class** `tarfile.TarInfo` (*name=""*)  
Create a `TarInfo` object.

`TarInfo.frombuf` (*buf*)  
Create and return a `TarInfo` object from string buffer *buf*. New in version 2.6: Raises `HeaderError` if the buffer is invalid..

`TarInfo.fromtarfile` (*tarfile*)  
Read the next member from the `TarFile` object *tarfile* and return it as a `TarInfo` object. New in version 2.6.

`TarInfo.tobuf` (*format=DEFAULT\_FORMAT, encoding=ENCODING, errors='strict'*)  
Create a string buffer from a `TarInfo` object. For information on the arguments see the constructor of the `TarFile` class. Changed in version 2.6: The arguments were added.

A `TarInfo` object has the following public data attributes:

`TarInfo.name`  
Name of the archive member.

`TarInfo.size`  
Size in bytes.

`TarInfo.mtime`  
Time of last modification.

`TarInfo.mode`  
Permission bits.

`TarInfo.type`  
File type. *type* is usually one of these constants: `REGTYPE`, `AREGTYPE`, `LNKTYPE`, `SYMTYPE`, `DIRTYPE`, `FIFOTYPE`, `CONTTYPE`, `CHRTYPE`, `BLKTYPE`, `GNUTYPE_SPARSE`. To determine the type of a `TarInfo` object more conveniently, use the `is_*()` methods below.

`TarInfo.linkname`  
Name of the target file name, which is only present in `TarInfo` objects of type `LNKTYPE` and `SYMTYPE`.

`TarInfo.uid`  
User ID of the user who originally stored this member.

`TarInfo.gid`  
Group ID of the user who originally stored this member.

`TarInfo.uname`  
User name.

`TarInfo.gname`  
Group name.

### `TarInfo.pax_headers`

A dictionary containing key-value pairs of an associated pax extended header. New in version 2.6.

A `TarInfo` object also provides some convenient query methods:

### `TarInfo.isfile()`

Return `True` if the `TarInfo` object is a regular file.

### `TarInfo.isreg()`

Same as `isfile()`.

### `TarInfo.isdir()`

Return `True` if it is a directory.

### `TarInfo.issym()`

Return `True` if it is a symbolic link.

### `TarInfo.islnk()`

Return `True` if it is a hard link.

### `TarInfo.ischr()`

Return `True` if it is a character device.

### `TarInfo.isblk()`

Return `True` if it is a block device.

### `TarInfo.isfifo()`

Return `True` if it is a FIFO.

### `TarInfo.isdev()`

Return `True` if it is one of character device, block device or FIFO.

## 12.5.3 Examples

How to extract an entire tar archive to the current working directory:

```
import tarfile
tar = tarfile.open("sample.tar.gz")
tar.extractall()
tar.close()
```

How to extract a subset of a tar archive with `TarFile.extractall()` using a generator function instead of a list:

```
import os
import tarfile

def py_files(members):
    for tarinfo in members:
        if os.path.splitext(tarinfo.name)[1] == ".py":
            yield tarinfo

tar = tarfile.open("sample.tar.gz")
tar.extractall(members=py_files(tar))
tar.close()
```

How to create an uncompressed tar archive from a list of filenames:

```
import tarfile
tar = tarfile.open("sample.tar", "w")
for name in ["foo", "bar", "quux"]:
```

```
tar.add(name)
tar.close()
```

The same example using the `with` statement:

```
import tarfile
with tarfile.open("sample.tar", "w") as tar:
    for name in ["foo", "bar", "quux"]:
        tar.add(name)
```

How to read a gzip compressed tar archive and display some member information:

```
import tarfile
tar = tarfile.open("sample.tar.gz", "r:gz")
for tarinfo in tar:
    print tarinfo.name, "is", tarinfo.size, "bytes in size and is",
    if tarinfo.isreg():
        print "a regular file."
    elif tarinfo.isdir():
        print "a directory."
    else:
        print "something else."
tar.close()
```

How to create an archive and reset the user information using the `filter` parameter in `TarFile.add()`:

```
import tarfile
def reset(tarinfo):
    tarinfo.uid = tarinfo.gid = 0
    tarinfo.uname = tarinfo.gname = "root"
    return tarinfo
tar = tarfile.open("sample.tar.gz", "w:gz")
tar.add("foo", filter=reset)
tar.close()
```

## 12.5.4 Supported tar formats

There are three tar formats that can be created with the `tarfile` module:

- The POSIX.1-1988 ustar format (`USTAR_FORMAT`). It supports filenames up to a length of at best 256 characters and linknames up to 100 characters. The maximum file size is 8 gigabytes. This is an old and limited but widely supported format.
- The GNU tar format (`GNU_FORMAT`). It supports long filenames and linknames, files bigger than 8 gigabytes and sparse files. It is the de facto standard on GNU/Linux systems. `tarfile` fully supports the GNU tar extensions for long names, sparse file support is read-only.
- The POSIX.1-2001 pax format (`PAX_FORMAT`). It is the most flexible format with virtually no limits. It supports long filenames and linknames, large files and stores pathnames in a portable way. However, not all tar implementations today are able to handle pax archives properly.

The *pax* format is an extension to the existing *ustar* format. It uses extra headers for information that cannot be stored otherwise. There are two flavours of pax headers: Extended headers only affect the subsequent file header, global headers are valid for the complete archive and affect all following files. All the data in a pax header is encoded in *UTF-8* for portability reasons.

There are some more variants of the tar format which can be read, but not created:

- The ancient V7 format. This is the first tar format from Unix Seventh Edition, storing only regular files and directories. Names must not be longer than 100 characters, there is no user/group name information. Some archives have miscalculated header checksums in case of fields with non-ASCII characters.
- The SunOS tar extended format. This format is a variant of the POSIX.1-2001 pax format, but is not compatible.

### 12.5.5 Unicode issues

The tar format was originally conceived to make backups on tape drives with the main focus on preserving file system information. Nowadays tar archives are commonly used for file distribution and exchanging archives over networks. One problem of the original format (that all other formats are merely variants of) is that there is no concept of supporting different character encodings. For example, an ordinary tar archive created on a *UTF-8* system cannot be read correctly on a *Latin-1* system if it contains non-ASCII characters. Names (i.e. filenames, linknames, user/group names) containing these characters will appear damaged. Unfortunately, there is no way to autodetect the encoding of an archive.

The pax format was designed to solve this problem. It stores non-ASCII names using the universal character encoding *UTF-8*. When a pax archive is read, these *UTF-8* names are converted to the encoding of the local file system.

The details of unicode conversion are controlled by the *encoding* and *errors* keyword arguments of the `TarFile` class.

The default value for *encoding* is the local character encoding. It is deduced from `sys.getfilesystemencoding()` and `sys.getdefaultencoding()`. In read mode, *encoding* is used exclusively to convert unicode names from a pax archive to strings in the local character encoding. In write mode, the use of *encoding* depends on the chosen archive format. In case of `PAX_FORMAT`, input names that contain non-ASCII characters need to be decoded before being stored as *UTF-8* strings. The other formats do not make use of *encoding* unless unicode objects are used as input names. These are converted to 8-bit character strings before they are added to the archive.

The *errors* argument defines how characters are treated that cannot be converted to or from *encoding*. Possible values are listed in section *Codec Base Classes*. In read mode, there is an additional scheme `'utf-8'` which means that bad characters are replaced by their *UTF-8* representation. This is the default scheme. In write mode the default value for *errors* is `'strict'` to ensure that name information is not altered unnoticed.

# FILE FORMATS

The modules described in this chapter parse various miscellaneous file formats that aren't markup languages or are related to e-mail.

## 13.1 `csv` — CSV File Reading and Writing

New in version 2.3. The so-called CSV (Comma Separated Values) format is the most common import and export format for spreadsheets and databases. There is no “CSV standard”, so the format is operationally defined by the many applications which read and write it. The lack of a standard means that subtle differences often exist in the data produced and consumed by different applications. These differences can make it annoying to process CSV files from multiple sources. Still, while the delimiters and quoting characters vary, the overall format is similar enough that it is possible to write a single module which can efficiently manipulate such data, hiding the details of reading and writing the data from the programmer.

The `csv` module implements classes to read and write tabular data in CSV format. It allows programmers to say, “write this data in the format preferred by Excel,” or “read data from this file which was generated by Excel,” without knowing the precise details of the CSV format used by Excel. Programmers can also describe the CSV formats understood by other applications or define their own special-purpose CSV formats.

The `csv` module's `reader` and `writer` objects read and write sequences. Programmers can also read and write data in dictionary form using the `DictReader` and `DictWriter` classes.

---

**Note:** This version of the `csv` module doesn't support Unicode input. Also, there are currently some issues regarding ASCII NUL characters. Accordingly, all input should be UTF-8 or printable ASCII to be safe; see the examples in section *Examples*.

---

### See Also:

**PEP 305 - CSV File API** The Python Enhancement Proposal which proposed this addition to Python.

### 13.1.1 Module Contents

The `csv` module defines the following functions:

`csv.reader (csvfile, dialect='excel', **fmtparams)`

Return a reader object which will iterate over lines in the given *csvfile*. *csvfile* can be any object which supports the *iterator* protocol and returns a string each time its `next ()` method is called — file objects and list objects are both suitable. If *csvfile* is a file object, it must be opened with the 'b' flag on platforms where that makes a difference. An optional *dialect* parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the `Dialect` class or one of the strings returned

by the `list_dialects()` function. The other optional *fmtparams* keyword arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*.

Each row read from the csv file is returned as a list of strings. No automatic data type conversion is performed.

A short usage example:

```
>>> import csv
>>> with open('eggs.csv', 'rb') as csvfile:
...     spamreader = csv.reader(csvfile, delimiter=' ', quotechar='|')
...     for row in spamreader:
...         print ', '.join(row)
Spam, Spam, Spam, Spam, Spam, Baked Beans
Spam, Lovely Spam, Wonderful Spam
```

Changed in version 2.5: The parser is now stricter with respect to multi-line quoted fields. Previously, if a line ended within a quoted field without a terminating newline character, a newline would be inserted into the returned field. This behavior caused problems when reading files which contained carriage return characters within fields. The behavior was changed to return the field without inserting newlines. As a consequence, if newlines embedded within fields are important, the input should be split into lines in a manner which preserves the newline characters.

`csv.writer(csvfile, dialect='excel', **fmtparams)`

Return a writer object responsible for converting the user's data into delimited strings on the given file-like object. *csvfile* can be any object with a `write()` method. If *csvfile* is a file object, it must be opened with the 'b' flag on platforms where that makes a difference. An optional *dialect* parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the `Dialect` class or one of the strings returned by the `list_dialects()` function. The other optional *fmtparams* keyword arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*. To make it as easy as possible to interface with modules which implement the DB API, the value `None` is written as the empty string. While this isn't a reversible transformation, it makes it easier to dump SQL NULL data values to CSV files without preprocessing the data returned from a `cursor.fetch*` call. All other non-string data are stringified with `str()` before being written.

A short usage example:

```
import csv
with open('eggs.csv', 'wb') as csvfile:
    spamwriter = csv.writer(csvfile, delimiter=' ',
                           quotechar='|', quoting=csv.QUOTE_MINIMAL)
    spamwriter.writerow(['Spam'] * 5 + ['Baked Beans'])
    spamwriter.writerow(['Spam', 'Lovely Spam', 'Wonderful Spam'])
```

`csv.register_dialect(name[, dialect], **fmtparams)`

Associate *dialect* with *name*. *name* must be a string or Unicode object. The dialect can be specified either by passing a sub-class of `Dialect`, or by *fmtparams* keyword arguments, or both, with keyword arguments overriding parameters of the dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*.

`csv.unregister_dialect(name)`

Delete the dialect associated with *name* from the dialect registry. An `Error` is raised if *name* is not a registered dialect name.

`csv.get_dialect(name)`

Return the dialect associated with *name*. An `Error` is raised if *name* is not a registered dialect name. Changed

in version 2.5: This function now returns an immutable `Dialect`. Previously an instance of the requested dialect was returned. Users could modify the underlying class, changing the behavior of active readers and writers.

`csv.list_dialects()`  
Return the names of all registered dialects.

`csv.field_size_limit([new_limit])`  
Returns the current maximum field size allowed by the parser. If `new_limit` is given, this becomes the new limit. New in version 2.5.

The `csv` module defines the following classes:

**class** `csv.DictReader` (*csvfile*, *fieldnames=None*, *restkey=None*, *restval=None*, *dialect='excel'*, \*args, \*\*kws)

Create an object which operates like a regular reader but maps the information read into a dict whose keys are given by the optional `fieldnames` parameter. If the `fieldnames` parameter is omitted, the values in the first row of the `csvfile` will be used as the fieldnames. If the row read has more fields than the fieldnames sequence, the remaining data is added as a sequence keyed by the value of `restkey`. If the row read has fewer fields than the fieldnames sequence, the remaining keys take the value of the optional `restval` parameter. Any other optional or keyword arguments are passed to the underlying `reader` instance.

**class** `csv.DictWriter` (*csvfile*, *fieldnames*, *restval=''*, *extrasaction='raise'*, *dialect='excel'*, \*args, \*\*kws)

Create an object which operates like a regular writer but maps dictionaries onto output rows. The `fieldnames` parameter identifies the order in which values in the dictionary passed to the `writerow()` method are written to the `csvfile`. The optional `restval` parameter specifies the value to be written if the dictionary is missing a key in `fieldnames`. If the dictionary passed to the `writerow()` method contains a key not found in `fieldnames`, the optional `extrasaction` parameter indicates what action to take. If it is set to `'raise'` a `ValueError` is raised. If it is set to `'ignore'`, extra values in the dictionary are ignored. Any other optional or keyword arguments are passed to the underlying `writer` instance.

Note that unlike the `DictReader` class, the `fieldnames` parameter of the `DictWriter` is not optional. Since Python's `dict` objects are not ordered, there is not enough information available to deduce the order in which the row should be written to the `csvfile`.

**class** `csv.Dialect`

The `Dialect` class is a container class relied on primarily for its attributes, which are used to define the parameters for a specific `reader` or `writer` instance.

**class** `csv.excel`

The `excel` class defines the usual properties of an Excel-generated CSV file. It is registered with the dialect name `'excel'`.

**class** `csv.excel_tab`

The `excel_tab` class defines the usual properties of an Excel-generated TAB-delimited file. It is registered with the dialect name `'excel-tab'`.

**class** `csv.Sniffer`

The `Sniffer` class is used to deduce the format of a CSV file.

The `Sniffer` class provides two methods:

**sniff** (*sample*, *delimiters=None*)

Analyze the given `sample` and return a `Dialect` subclass reflecting the parameters found. If the optional `delimiters` parameter is given, it is interpreted as a string containing possible valid delimiter characters.

**has\_header** (*sample*)

Analyze the sample text (presumed to be in CSV format) and return `True` if the first row appears to be a series of column headers.

An example for `Sniffer` use:

```
with open('example.csv', 'rb') as csvfile:
    dialect = csv.Sniffer().sniff(csvfile.read(1024))
    csvfile.seek(0)
    reader = csv.reader(csvfile, dialect)
    # ... process CSV file contents here ...
```

The `csv` module defines the following constants:

**csv.QUOTE\_ALL**

Instructs `writer` objects to quote all fields.

**csv.QUOTE\_MINIMAL**

Instructs `writer` objects to only quote those fields which contain special characters such as *delimiter*, *quotechar* or any of the characters in *lineterminator*.

**csv.QUOTE\_NONNUMERIC**

Instructs `writer` objects to quote all non-numeric fields.

Instructs the reader to convert all non-quoted fields to type *float*.

**csv.QUOTE\_NONE**

Instructs `writer` objects to never quote fields. When the current *delimiter* occurs in output data it is preceded by the current *escapechar* character. If *escapechar* is not set, the writer will raise `Error` if any characters that require escaping are encountered.

Instructs `reader` to perform no special processing of quote characters.

The `csv` module defines the following exception:

**exception csv.Error**

Raised by any of the functions when an error is detected.

### 13.1.2 Dialects and Formatting Parameters

To make it easier to specify the format of input and output records, specific formatting parameters are grouped together into dialects. A dialect is a subclass of the `Dialect` class having a set of specific methods and a single `validate()` method. When creating `reader` or `writer` objects, the programmer can specify a string or a subclass of the `Dialect` class as the dialect parameter. In addition to, or instead of, the *dialect* parameter, the programmer can also specify individual formatting parameters, which have the same names as the attributes defined below for the `Dialect` class.

Dialects support the following attributes:

**Dialect.delimiter**

A one-character string used to separate fields. It defaults to `' , '`.

**Dialect.doublequote**

Controls how instances of *quotechar* appearing inside a field should be themselves be quoted. When `True`, the character is doubled. When `False`, the *escapechar* is used as a prefix to the *quotechar*. It defaults to `True`.

On output, if *doublequote* is `False` and no *escapechar* is set, `Error` is raised if a *quotechar* is found in a field.

**Dialect.escapechar**

A one-character string used by the writer to escape the *delimiter* if *quoting* is set to `QUOTE_NONE` and the *quotechar* if *doublequote* is `False`. On reading, the *escapechar* removes any special meaning from the following character. It defaults to `None`, which disables escaping.

**Dialect.lineterminator**

The string used to terminate lines produced by the `writer`. It defaults to `'\r\n'`.

---

**Note:** The `reader` is hard-coded to recognise either `'\r'` or `'\n'` as end-of-line, and ignores *lineterminator*. This behavior may change in the future.

---

**Dialect.quotechar**

A one-character string used to quote fields containing special characters, such as the *delimiter* or *quotechar*, or which contain new-line characters. It defaults to `'"`.

**Dialect.quoting**

Controls when quotes should be generated by the writer and recognised by the reader. It can take on any of the `QUOTE_*` constants (see section *Module Contents*) and defaults to `QUOTE_MINIMAL`.

**Dialect.skipinitialspace**

When `True`, whitespace immediately following the *delimiter* is ignored. The default is `False`.

### 13.1.3 Reader Objects

Reader objects (`DictReader` instances and objects returned by the `reader()` function) have the following public methods:

`csvreader.next()`

Return the next row of the reader's iterable object as a list, parsed according to the current dialect.

Reader objects have the following public attributes:

`csvreader.dialect`

A read-only description of the dialect in use by the parser.

`csvreader.line_num`

The number of lines read from the source iterator. This is not the same as the number of records returned, as records can span multiple lines. New in version 2.5.

`DictReader` objects have the following public attribute:

`csvreader.fieldnames`

If not passed as a parameter when creating the object, this attribute is initialized upon first access or when the first record is read from the file. Changed in version 2.6.

### 13.1.4 Writer Objects

Writer objects (`DictWriter` instances and objects returned by the `writer()` function) have the following public methods. A *row* must be a sequence of strings or numbers for `Writer` objects and a dictionary mapping fieldnames to strings or numbers (by passing them through `str()` first) for `DictWriter` objects. Note that complex numbers are written out surrounded by parens. This may cause some problems for other programs which read CSV files (assuming they support complex numbers at all).

`csvwriter.writerow(row)`

Write the *row* parameter to the writer's file object, formatted according to the current dialect.

`csvwriter.writerows(rows)`

Write all the *rows* parameters (a list of *row* objects as described above) to the writer's file object, formatted according to the current dialect.

Writer objects have the following public attribute:

`csvwriter.dialect`

A read-only description of the dialect in use by the writer.

DictWriter objects have the following public method:

```
DictWriter.writeheader()
```

Write a row with the field names (as specified in the constructor). New in version 2.7.

### 13.1.5 Examples

The simplest example of reading a CSV file:

```
import csv
with open('some.csv', 'rb') as f:
    reader = csv.reader(f)
    for row in reader:
        print row
```

Reading a file with an alternate format:

```
import csv
with open('passwd', 'rb') as f:
    reader = csv.reader(f, delimiter=':', quoting=csv.QUOTE_NONE)
    for row in reader:
        print row
```

The corresponding simplest possible writing example is:

```
import csv
with open('some.csv', 'wb') as f:
    writer = csv.writer(f)
    writer.writerows(someiterable)
```

Registering a new dialect:

```
import csv
csv.register_dialect('unixpwd', delimiter=':', quoting=csv.QUOTE_NONE)
with open('passwd', 'rb') as f:
    reader = csv.reader(f, 'unixpwd')
```

A slightly more advanced use of the reader — catching and reporting errors:

```
import csv, sys
filename = 'some.csv'
with open(filename, 'rb') as f:
    reader = csv.reader(f)
    try:
        for row in reader:
            print row
    except csv.Error, e:
        sys.exit('file %s, line %d: %s' % (filename, reader.line_num, e))
```

And while the module doesn't directly support parsing strings, it can easily be done:

```
import csv
for row in csv.reader(['one,two,three']):
    print row
```

The `csv` module doesn't directly support reading and writing Unicode, but it is 8-bit-clean save for some problems with ASCII NUL characters. So you can write functions or classes that handle the encoding and decoding for you as long as you avoid encodings like UTF-16 that use NULs. UTF-8 is recommended.

`unicode_csv_reader()` below is a *generator* that wraps `csv.reader` to handle Unicode CSV data (a list of Unicode strings). `utf_8_encoder()` is a *generator* that encodes the Unicode strings as UTF-8, one string (or row) at a time. The encoded strings are parsed by the CSV reader, and `unicode_csv_reader()` decodes the UTF-8-encoded cells back into Unicode:

```
import csv

def unicode_csv_reader(unicode_csv_data, dialect=csv.excel, **kwargs):
    # csv.py doesn't do Unicode; encode temporarily as UTF-8:
    csv_reader = csv.reader(utf_8_encoder(unicode_csv_data),
                           dialect=dialect, **kwargs)
    for row in csv_reader:
        # decode UTF-8 back to Unicode, cell by cell:
        yield [unicode(cell, 'utf-8') for cell in row]

def utf_8_encoder(unicode_csv_data):
    for line in unicode_csv_data:
        yield line.encode('utf-8')
```

For all other encodings the following `UnicodeReader` and `UnicodeWriter` classes can be used. They take an additional *encoding* parameter in their constructor and make sure that the data passes the real reader or writer encoded as UTF-8:

```
import csv, codecs, cStringIO

class UTF8Recoder:
    """
    Iterator that reads an encoded stream and reencodes the input to UTF-8
    """
    def __init__(self, f, encoding):
        self.reader = codecs.getreader(encoding)(f)

    def __iter__(self):
        return self

    def next(self):
        return self.reader.next().encode("utf-8")

class UnicodeReader:
    """
    A CSV reader which will iterate over lines in the CSV file "f",
    which is encoded in the given encoding.
    """
    def __init__(self, f, dialect=csv.excel, encoding="utf-8", **kwds):
        f = UTF8Recoder(f, encoding)
        self.reader = csv.reader(f, dialect=dialect, **kwds)

    def next(self):
        row = self.reader.next()
        return [unicode(s, "utf-8") for s in row]

    def __iter__(self):
        return self
```

```
class UnicodeWriter:
    """
    A CSV writer which will write rows to CSV file "f",
    which is encoded in the given encoding.
    """

    def __init__(self, f, dialect=csv.excel, encoding="utf-8", **kwds):
        # Redirect output to a queue
        self.queue = cStringIO.StringIO()
        self.writer = csv.writer(self.queue, dialect=dialect, **kwds)
        self.stream = f
        self.encoder = codecs.getincrementalencoder(encoding) ()

    def writerow(self, row):
        self.writer.writerow([s.encode("utf-8") for s in row])
        # Fetch UTF-8 output from the queue ...
        data = self.queue.getvalue()
        data = data.decode("utf-8")
        # ... and reencode it into the target encoding
        data = self.encoder.encode(data)
        # write to the target stream
        self.stream.write(data)
        # empty queue
        self.queue.truncate(0)

    def writerows(self, rows):
        for row in rows:
            self.writerow(row)
```

## 13.2 ConfigParser — Configuration file parser

---

**Note:** The `ConfigParser` module has been renamed to `configparser` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

This module defines the class `ConfigParser`. The `ConfigParser` class implements a basic configuration file parser language which provides a structure similar to what you would find on Microsoft Windows INI files. You can use this to write Python programs which can be customized by end users easily.

---

**Note:** This library does *not* interpret or write the value-type prefixes used in the Windows Registry extended version of INI syntax.

---

### See Also:

**Module `shlex`** Support for a creating Unix shell-like mini-languages which can be used as an alternate format for application configuration files.

**Module `json`** The `json` module implements a subset of JavaScript syntax which can also be used for this purpose.

The configuration file consists of sections, led by a `[section]` header and followed by `name: value` entries, with continuations in the style of

**RFC 822** (see section 3.1.1, “LONG HEADER FIELDS”); `name=value` is also accepted. Note that leading whitespace is removed from values. The optional values can contain format strings which refer to other values in the same

section, or values in a special `DEFAULT` section. Additional defaults can be provided on initialization and retrieval. Lines beginning with `' #'` or `' ;'` are ignored and may be used to provide comments.

Configuration files may include comments, prefixed by specific characters (`#` and `;`). Comments may appear on their own in an otherwise empty line, or may be entered in lines holding values or section names. In the latter case, they need to be preceded by a whitespace character to be recognized as a comment. (For backwards compatibility, only `;` starts an inline comment, while `#` does not.)

On top of the core functionality, `SafeConfigParser` supports interpolation. This means values can contain format strings which refer to other values in the same section, or values in a special `DEFAULT` section. Additional defaults can be provided on initialization.

For example:

```
[My Section]
foodir: %(dir)s/whatever
dir=frob
long: this value continues
      in the next line
```

would resolve the `%(dir)s` to the value of `dir` (`frob` in this case). All reference expansions are done on demand.

Default values can be specified by passing them into the `ConfigParser` constructor as a dictionary. Additional defaults may be passed into the `get()` method which will override all others.

Sections are normally stored in a built-in dictionary. An alternative dictionary type can be passed to the `ConfigParser` constructor. For example, if a dictionary type is passed that sorts its keys, the sections will be sorted on write-back, as will be the keys within each section.

**class** `ConfigParser.RawConfigParser` (`[defaults[, dict_type[, allow_no_value ]]`)

The basic configuration object. When `defaults` is given, it is initialized into the dictionary of intrinsic defaults. When `dict_type` is given, it will be used to create the dictionary objects for the list of sections, for the options within a section, and for the default values. When `allow_no_value` is true (default: `False`), options without values are accepted; the value presented for these is `None`.

This class does not support the magical interpolation behavior.

All option names are passed through the `optionxform()` method. Its default implementation converts option names to lower case. New in version 2.3.Changed in version 2.6: `dict_type` was added.Changed in version 2.7: The default `dict_type` is `collections.OrderedDict`. `allow_no_value` was added.

**class** `ConfigParser.ConfigParser` (`[defaults[, dict_type[, allow_no_value ]]`)

Derived class of `RawConfigParser` that implements the magical interpolation feature and adds optional arguments to the `get()` and `items()` methods. The values in `defaults` must be appropriate for the `%( )s` string interpolation. Note that `__name__` is an intrinsic default; its value is the section name, and will override any value provided in `defaults`.

All option names used in interpolation will be passed through the `optionxform()` method just like any other option name reference. Using the default implementation of `optionxform()`, the values `foo %(bar)s` and `foo %(BAR)s` are equivalent. New in version 2.3.Changed in version 2.6: `dict_type` was added.Changed in version 2.7: The default `dict_type` is `collections.OrderedDict`. `allow_no_value` was added.

**class** `ConfigParser.SafeConfigParser` (`[defaults[, dict_type[, allow_no_value ]]`)

Derived class of `ConfigParser` that implements a more-sane variant of the magical interpolation feature. This implementation is more predictable as well. New applications should prefer this version if they don't need to be compatible with older versions of Python. New in version 2.3.Changed in version 2.6: `dict_type` was added.Changed in version 2.7: The default `dict_type` is `collections.OrderedDict`. `allow_no_value` was added.

**exception** `ConfigParser.Error`

Base class for all other configparser exceptions.

**exception** `ConfigParser.NoSectionError`

Exception raised when a specified section is not found.

**exception** `ConfigParser.DuplicateSectionError`

Exception raised if `add_section()` is called with the name of a section that is already present.

**exception** `ConfigParser.NoOptionError`

Exception raised when a specified option is not found in the specified section.

**exception** `ConfigParser.InterpolationError`

Base class for exceptions raised when problems occur performing string interpolation.

**exception** `ConfigParser.InterpolationDepthError`

Exception raised when string interpolation cannot be completed because the number of iterations exceeds `MAX_INTERPOLATION_DEPTH`. Subclass of `InterpolationError`.

**exception** `ConfigParser.InterpolationMissingOptionError`

Exception raised when an option referenced from a value does not exist. Subclass of `InterpolationError`. New in version 2.3.

**exception** `ConfigParser.InterpolationSyntaxError`

Exception raised when the source text into which substitutions are made does not conform to the required syntax. Subclass of `InterpolationError`. New in version 2.3.

**exception** `ConfigParser.MissingSectionHeaderError`

Exception raised when attempting to parse a file which has no section headers.

**exception** `ConfigParser.ParsingError`

Exception raised when errors occur attempting to parse a file.

`ConfigParser.MAX_INTERPOLATION_DEPTH`

The maximum depth for recursive interpolation for `get()` when the `raw` parameter is false. This is relevant only for the `ConfigParser` class.

**See Also:**

**Module `shlex`** Support for a creating Unix shell-like mini-languages which can be used as an alternate format for application configuration files.

## 13.2.1 RawConfigParser Objects

`RawConfigParser` instances have the following methods:

`RawConfigParser.defaults()`

Return a dictionary containing the instance-wide defaults.

`RawConfigParser.sections()`

Return a list of the sections available; `DEFAULT` is not included in the list.

`RawConfigParser.add_section(section)`

Add a section named `section` to the instance. If a section by the given name already exists, `DuplicateSectionError` is raised. If the name `DEFAULT` (or any of its case-insensitive variants) is passed, `ValueError` is raised.

`RawConfigParser.has_section(section)`

Indicates whether the named section is present in the configuration. The `DEFAULT` section is not acknowledged.

`RawConfigParser.options(section)`

Returns a list of options available in the specified `section`.

`RawConfigParser.has_option` (*section*, *option*)

If the given section exists, and contains the given option, return `True`; otherwise return `False`. New in version 1.6.

`RawConfigParser.read` (*filenames*)

Attempt to read and parse a list of filenames, returning a list of filenames which were successfully parsed. If *filenames* is a string or Unicode string, it is treated as a single filename. If a file named in *filenames* cannot be opened, that file will be ignored. This is designed so that you can specify a list of potential configuration file locations (for example, the current directory, the user's home directory, and some system-wide directory), and all existing configuration files in the list will be read. If none of the named files exist, the `ConfigParser` instance will contain an empty dataset. An application which requires initial values to be loaded from a file should load the required file or files using `readfp()` before calling `read()` for any optional files:

```
import ConfigParser, os
```

```
config = ConfigParser.ConfigParser()
config.readfp(open('defaults.cfg'))
config.read(['site.cfg', os.path.expanduser('~/.myapp.cfg')])
```

Changed in version 2.4: Returns list of successfully parsed filenames.

`RawConfigParser.readfp` (*fp*[, *filename* ])

Read and parse configuration data from the file or file-like object in *fp* (only the `readline()` method is used). If *filename* is omitted and *fp* has a name attribute, that is used for *filename*; the default is `<???`.

`RawConfigParser.get` (*section*, *option*)

Get an *option* value for the named *section*.

`RawConfigParser.getint` (*section*, *option*)

A convenience method which coerces the *option* in the specified *section* to an integer.

`RawConfigParser.getfloat` (*section*, *option*)

A convenience method which coerces the *option* in the specified *section* to a floating point number.

`RawConfigParser.getboolean` (*section*, *option*)

A convenience method which coerces the *option* in the specified *section* to a Boolean value. Note that the accepted values for the option are "1", "yes", "true", and "on", which cause this method to return `True`, and "0", "no", "false", and "off", which cause it to return `False`. These string values are checked in a case-insensitive manner. Any other value will cause it to raise `ValueError`.

`RawConfigParser.items` (*section*)

Return a list of (name, value) pairs for each option in the given *section*.

`RawConfigParser.set` (*section*, *option*, *value*)

If the given section exists, set the given option to the specified value; otherwise raise `NoSectionError`. While it is possible to use `RawConfigParser` (or `ConfigParser` with `raw` parameters set to true) for internal storage of non-string values, full functionality (including interpolation and output to files) can only be achieved using string values. New in version 1.6.

`RawConfigParser.write` (*fileobject*)

Write a representation of the configuration to the specified file object. This representation can be parsed by a future `read()` call. New in version 1.6.

`RawConfigParser.remove_option` (*section*, *option*)

Remove the specified *option* from the specified *section*. If the section does not exist, raise `NoSectionError`. If the option existed to be removed, return `True`; otherwise return `False`. New in version 1.6.

`RawConfigParser.remove_section` (*section*)

Remove the specified *section* from the configuration. If the section in fact existed, return `True`. Otherwise

```
return False.
```

`RawConfigParser.optionxform(option)`

Transforms the option name *option* as found in an input file or as passed in by client code to the form that should be used in the internal structures. The default implementation returns a lower-case version of *option*; subclasses may override this or client code can set an attribute of this name on instances to affect this behavior.

You don't necessarily need to subclass a `ConfigParser` to use this method, you can also re-set it on an instance, to a function that takes a string argument. Setting it to `str`, for example, would make option names case sensitive:

```
cfgparser = ConfigParser()
...
cfgparser.optionxform = str
```

Note that when reading configuration files, whitespace around the option names are stripped before `optionxform()` is called.

## 13.2.2 ConfigParser Objects

The `ConfigParser` class extends some methods of the `RawConfigParser` interface, adding some optional arguments.

`ConfigParser.get(section, option[, raw[, vars]])`

Get an *option* value for the named *section*. If *vars* is provided, it must be a dictionary. The *option* is looked up in *vars* (if provided), *section*, and in *defaults* in that order.

All the `'%'` interpolations are expanded in the return values, unless the *raw* argument is true. Values for interpolation keys are looked up in the same manner as the option.

`ConfigParser.items(section[, raw[, vars]])`

Return a list of (name, value) pairs for each option in the given *section*. Optional arguments have the same meaning as for the `get()` method. New in version 2.3.

## 13.2.3 SafeConfigParser Objects

The `SafeConfigParser` class implements the same extended interface as `ConfigParser`, with the following addition:

`SafeConfigParser.set(section, option, value)`

If the given section exists, set the given option to the specified value; otherwise raise `NoSectionError`. *value* must be a string (`str` or `unicode`); if not, `TypeError` is raised. New in version 2.4.

## 13.2.4 Examples

An example of writing to a configuration file:

```
import ConfigParser
```

```
config = ConfigParser.RawConfigParser()
```

```
# When adding sections or items, add them in the reverse order of
# how you want them to be displayed in the actual file.
# In addition, please note that using RawConfigParser's and the raw
# mode of ConfigParser's respective set functions, you can assign
# non-string values to keys internally, but will receive an error
```

```

# when attempting to write to a file or when you get it in non-raw
# mode. SafeConfigParser does not allow such assignments to take place.
config.add_section('Section1')
config.set('Section1', 'int', '15')
config.set('Section1', 'bool', 'true')
config.set('Section1', 'float', '3.1415')
config.set('Section1', 'baz', 'fun')
config.set('Section1', 'bar', 'Python')
config.set('Section1', 'foo', '%(bar)s is %(baz)s!')

# Writing our configuration file to 'example.cfg'
with open('example.cfg', 'wb') as configfile:
    config.write(configfile)

```

An example of reading the configuration file again:

```
import ConfigParser
```

```

config = ConfigParser.RawConfigParser()
config.read('example.cfg')

# getfloat() raises an exception if the value is not a float
# getint() and getboolean() also do this for their respective types
float = config.getfloat('Section1', 'float')
int = config.getint('Section1', 'int')
print float + int

# Notice that the next output does not interpolate '%(bar)s' or '%(baz)s'.
# This is because we are using a RawConfigParser().
if config.getboolean('Section1', 'bool'):
    print config.get('Section1', 'foo')

```

To get interpolation, you will need to use a `ConfigParser` or `SafeConfigParser`:

```
import ConfigParser
```

```

config = ConfigParser.ConfigParser()
config.read('example.cfg')

# Set the third, optional argument of get to 1 if you wish to use raw mode.
print config.get('Section1', 'foo', 0) # -> "Python is fun!"
print config.get('Section1', 'foo', 1) # -> "%(bar)s is %(baz)s!"

# The optional fourth argument is a dict with members that will take
# precedence in interpolation.
print config.get('Section1', 'foo', 0, {'bar': 'Documentation',
                                       'baz': 'evil'})

```

Defaults are available in all three types of `ConfigParsers`. They are used in interpolation if an option used is not defined elsewhere.

```
import ConfigParser
```

```

# New instance with 'bar' and 'baz' defaulting to 'Life' and 'hard' each
config = ConfigParser.SafeConfigParser({'bar': 'Life', 'baz': 'hard'})
config.read('example.cfg')

```

```
print config.get('Section1', 'foo') # -> "Python is fun!"
config.remove_option('Section1', 'bar')
config.remove_option('Section1', 'baz')
print config.get('Section1', 'foo') # -> "Life is hard!"
```

The function `opt_move` below can be used to move options between sections:

```
def opt_move(config, section1, section2, option):
    try:
        config.set(section2, option, config.get(section1, option, 1))
    except ConfigParser.NoSectionError:
        # Create non-existent section
        config.add_section(section2)
        opt_move(config, section1, section2, option)
    else:
        config.remove_option(section1, option)
```

Some configuration files are known to include settings without values, but which otherwise conform to the syntax supported by `ConfigParser`. The `allow_no_value` parameter to the constructor can be used to indicate that such values should be accepted:

```
>>> import ConfigParser
>>> import io

>>> sample_config = """
... [mysqld]
... user = mysql
... pid-file = /var/run/mysqld/mysqld.pid
... skip-external-locking
... old_passwords = 1
... skip-bdb
... skip-innodb
... """
>>> config = ConfigParser.RawConfigParser(allow_no_value=True)
>>> config.readfp(io.BytesIO(sample_config))

>>> # Settings with values are treated as before:
>>> config.get("mysqld", "user")
'mysql'

>>> # Settings without values provide None:
>>> config.get("mysqld", "skip-bdb")

>>> # Settings which aren't specified still raise an error:
>>> config.get("mysqld", "does-not-exist")
Traceback (most recent call last):
...
ConfigParser.NoOptionError: No option 'does-not-exist' in section: 'mysqld'
```

## 13.3 robotparser — Parser for robots.txt

---

**Note:** The `robotparser` module has been renamed `urllib.robotparser` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

This module provides a single class, `RobotFileParser`, which answers questions about whether or not a particular user agent can fetch a URL on the Web site that published the `robots.txt` file. For more details on the structure of `robots.txt` files, see <http://www.robotstxt.org/orig.html>.

**class** `robotparser.RobotFileParser`

This class provides a set of methods to read, parse and answer questions about a single `robots.txt` file.

**set\_url** (*url*)

Sets the URL referring to a `robots.txt` file.

**read** ()

Reads the `robots.txt` URL and feeds it to the parser.

**parse** (*lines*)

Parses the *lines* argument.

**can\_fetch** (*useragent*, *url*)

Returns `True` if the *useragent* is allowed to fetch the *url* according to the rules contained in the parsed `robots.txt` file.

**mtime** ()

Returns the time the `robots.txt` file was last fetched. This is useful for long-running web spiders that need to check for new `robots.txt` files periodically.

**modified** ()

Sets the time the `robots.txt` file was last fetched to the current time.

The following example demonstrates basic use of the `RobotFileParser` class.

```
>>> import robotparser
>>> rp = robotparser.RobotFileParser()
>>> rp.set_url("http://www.musi-cal.com/robots.txt")
>>> rp.read()
>>> rp.can_fetch("*", "http://www.musi-cal.com/cgi-bin/search?city=San+Francisco")
False
>>> rp.can_fetch("*", "http://www.musi-cal.com/")
True
```

## 13.4 netrc — netrc file processing

New in version 1.5.2. **Source code:** [Lib/netrc.py](#)

The `netrc` class parses and encapsulates the `netrc` file format used by the Unix `ftp` program and other FTP clients.

**class** `netrc.netrc` (*[file]*)

A `netrc` instance or subclass instance encapsulates data from a `netrc` file. The initialization argument, if present, specifies the file to parse. If no argument is given, the file `.netrc` in the user's home directory will be read. Parse errors will raise `NetrcParseError` with diagnostic information including the file name, line number, and terminating token.

**exception** `netrc.NetrcParseError`

Exception raised by the `netrc` class when syntactical errors are encountered in source text. Instances of this exception provide three interesting attributes: `msg` is a textual explanation of the error, `filename` is the name of the source file, and `lineno` gives the line number on which the error was found.

## 13.4.1 netrc Objects

A `netrc` instance has the following methods:

`netrc.authenticators` (*host*)

Return a 3-tuple (`login`, `account`, `password`) of authenticators for *host*. If the `netrc` file did not contain an entry for the given host, return the tuple associated with the 'default' entry. If neither matching host nor default entry is available, return `None`.

`netrc.__repr__` ()

Dump the class data as a string in the format of a `netrc` file. (This discards comments and may reorder the entries.)

Instances of `netrc` have public instance variables:

`netrc.hosts`

Dictionary mapping host names to (`login`, `account`, `password`) tuples. The 'default' entry, if any, is represented as a pseudo-host by that name.

`netrc.macros`

Dictionary mapping macro names to string lists.

---

**Note:** Passwords are limited to a subset of the ASCII character set. Versions of this module prior to 2.3 were extremely limited. Starting with 2.3, all ASCII punctuation is allowed in passwords. However, note that whitespace and non-printable characters are not allowed in passwords. This is a limitation of the way the `.netrc` file is parsed and may be removed in the future.

---

## 13.5 xdrlib — Encode and decode XDR data

**Source code:** [Lib/xdrlib.py](#)

---

The `xdrlib` module supports the External Data Representation Standard as described in [RFC 1014](#), written by Sun Microsystems, Inc. June 1987. It supports most of the data types described in the RFC.

The `xdrlib` module defines two classes, one for packing variables into XDR representation, and another for unpacking from XDR representation. There are also two exception classes.

**class** `xdrlib.Packer`

`Packer` is the class for packing data into XDR representation. The `Packer` class is instantiated with no arguments.

**class** `xdrlib.Unpacker` (*data*)

`Unpacker` is the complementary class which unpacks XDR data values from a string buffer. The input buffer is given as *data*.

**See Also:**

**RFC 1014 - XDR: External Data Representation Standard** This RFC defined the encoding of data which was XDR at the time this module was originally written. It has apparently been obsoleted by [RFC 1832](#).

**RFC 1832 - XDR: External Data Representation Standard** Newer RFC that provides a revised definition of XDR.

### 13.5.1 Packer Objects

`Packer` instances have the following methods:

`Packer.get_buffer()`

Returns the current pack buffer as a string.

`Packer.reset()`

Resets the pack buffer to the empty string.

In general, you can pack any of the most common XDR data types by calling the appropriate `pack_type()` method. Each method takes a single argument, the value to pack. The following simple data type packing methods are supported: `pack_uint()`, `pack_int()`, `pack_enum()`, `pack_bool()`, `pack_uhyper()`, and `pack_hyper()`.

`Packer.pack_float(value)`

Packs the single-precision floating point number *value*.

`Packer.pack_double(value)`

Packs the double-precision floating point number *value*.

The following methods support packing strings, bytes, and opaque data:

`Packer.pack_fstring(n, s)`

Packs a fixed length string, *s*. *n* is the length of the string but it is *not* packed into the data buffer. The string is padded with null bytes if necessary to guaranteed 4 byte alignment.

`Packer.pack_fopaque(n, data)`

Packs a fixed length opaque data stream, similarly to `pack_fstring()`.

`Packer.pack_string(s)`

Packs a variable length string, *s*. The length of the string is first packed as an unsigned integer, then the string data is packed with `pack_fstring()`.

`Packer.pack_opaque(data)`

Packs a variable length opaque data string, similarly to `pack_string()`.

`Packer.pack_bytes(bytes)`

Packs a variable length byte stream, similarly to `pack_string()`.

The following methods support packing arrays and lists:

`Packer.pack_list(list, pack_item)`

Packs a *list* of homogeneous items. This method is useful for lists with an indeterminate size; i.e. the size is not available until the entire list has been walked. For each item in the list, an unsigned integer 1 is packed first, followed by the data value from the list. *pack\_item* is the function that is called to pack the individual item. At the end of the list, an unsigned integer 0 is packed.

For example, to pack a list of integers, the code might appear like this:

```
import xdrlib
p = xdrlib.Packer()
p.pack_list([1, 2, 3], p.pack_int)
```

`Packer.pack_farray(n, array, pack_item)`

Packs a fixed length list (*array*) of homogeneous items. *n* is the length of the list; it is *not* packed into the buffer, but a `ValueError` exception is raised if `len(array)` is not equal to *n*. As above, *pack\_item* is the function used to pack each element.

`Packer.pack_array(list, pack_item)`

Packs a variable length *list* of homogeneous items. First, the length of the list is packed as an unsigned integer, then each element is packed as in `pack_farray()` above.

## 13.5.2 Unpacker Objects

The `Unpacker` class offers the following methods:

`Unpacker.reset(data)`

Resets the string buffer with the given *data*.

`Unpacker.get_position()`

Returns the current unpack position in the data buffer.

`Unpacker.set_position(position)`

Sets the data buffer unpack position to *position*. You should be careful about using `get_position()` and `set_position()`.

`Unpacker.get_buffer()`

Returns the current unpack data buffer as a string.

`Unpacker.done()`

Indicates unpack completion. Raises an `Error` exception if all of the data has not been unpacked.

In addition, every data type that can be packed with a `Packer`, can be unpacked with an `Unpacker`. Unpacking methods are of the form `unpack_type()`, and take no arguments. They return the unpacked object.

`Unpacker.unpack_float()`

Unpacks a single-precision floating point number.

`Unpacker.unpack_double()`

Unpacks a double-precision floating point number, similarly to `unpack_float()`.

In addition, the following methods unpack strings, bytes, and opaque data:

`Unpacker.unpack_fstring(n)`

Unpacks and returns a fixed length string. *n* is the number of characters expected. Padding with null bytes to guaranteed 4 byte alignment is assumed.

`Unpacker.unpack_fopaque(n)`

Unpacks and returns a fixed length opaque data stream, similarly to `unpack_fstring()`.

`Unpacker.unpack_string()`

Unpacks and returns a variable length string. The length of the string is first unpacked as an unsigned integer, then the string data is unpacked with `unpack_fstring()`.

`Unpacker.unpack_opaque()`

Unpacks and returns a variable length opaque data string, similarly to `unpack_string()`.

`Unpacker.unpack_bytes()`

Unpacks and returns a variable length byte stream, similarly to `unpack_string()`.

The following methods support unpacking arrays and lists:

`Unpacker.unpack_list(unpack_item)`

Unpacks and returns a list of homogeneous items. The list is unpacked one element at a time by first unpacking an unsigned integer flag. If the flag is 1, then the item is unpacked and appended to the list. A flag of 0 indicates the end of the list. *unpack\_item* is the function that is called to unpack the items.

`Unpacker.unpack_farray(n, unpack_item)`

Unpacks and returns (as a list) a fixed length array of homogeneous items. *n* is number of list elements to expect in the buffer. As above, *unpack\_item* is the function used to unpack each element.

`Unpacker.unpack_array(unpack_item)`

Unpacks and returns a variable length *list* of homogeneous items. First, the length of the list is unpacked as an unsigned integer, then each element is unpacked as in `unpack_farray()` above.

### 13.5.3 Exceptions

Exceptions in this module are coded as class instances:

**exception** `xdrllib.Error`

The base exception class. `Error` has a single public attribute `msg` containing the description of the error.

**exception** `xdrllib.ConversionError`

Class derived from `Error`. Contains no additional instance variables.

Here is an example of how you would catch one of these exceptions:

```
import xdrllib
p = xdrllib.Packer()
try:
    p.pack_double(8.01)
except xdrllib.ConversionError, instance:
    print 'packing the double failed:', instance.msg
```

## 13.6 plistlib — Generate and parse Mac OS X .plist files

Changed in version 2.6: This module was previously only available in the Mac-specific library, it is now available for all platforms. **Source code:** [Lib/plistlib.py](#)

This module provides an interface for reading and writing the “property list” XML files used mainly by Mac OS X.

The property list (`.plist`) file format is a simple XML pickle supporting basic object types, like dictionaries, lists, numbers and strings. Usually the top level object is a dictionary.

Values can be strings, integers, floats, booleans, tuples, lists, dictionaries (but only with string keys), `Data` or `datetime.datetime` objects. String values (including dictionary keys) may be unicode strings – they will be written out as UTF-8.

The `<data>` plist type is supported through the `Data` class. This is a thin wrapper around a Python string. Use `Data` if your strings contain control characters.

**See Also:**

**PList manual page** Apple’s documentation of the file format.

This module defines the following functions:

`plistlib.readPlist(pathOrFile)`

Read a plist file. `pathOrFile` may either be a file name or a (readable) file object. Return the unpacked root object (which usually is a dictionary).

The XML data is parsed using the Expat parser from `xml.parsers.expat` – see its documentation for possible exceptions on ill-formed XML. Unknown elements will simply be ignored by the plist parser.

`plistlib.writePlist(rootObject, pathOrFile)`

Write `rootObject` to a plist file. `pathOrFile` may either be a file name or a (writable) file object.

A `TypeError` will be raised if the object is of an unsupported type or a container that contains objects of unsupported types.

`plistlib.readPlistFromString` (*data*)  
Read a plist from a string. Return the root object.

`plistlib.writePlistToString` (*rootObject*)  
Return *rootObject* as a plist-formatted string.

`plistlib.readPlistFromResource` (*path*, *restype*='plst', *resid*=0)  
Read a plist from the resource with type *restype* from the resource fork of *path*. Availability: Mac OS X.

---

**Note:** In Python 3.x, this function has been removed.

---

`plistlib.writePlistToResource` (*rootObject*, *path*, *restype*='plst', *resid*=0)  
Write *rootObject* as a resource with type *restype* to the resource fork of *path*. Availability: Mac OS X.

---

**Note:** In Python 3.x, this function has been removed.

---

The following class is available:

**class** `plistlib.Data` (*data*)  
Return a “data” wrapper object around the string *data*. This is used in functions converting from/to plists to represent the <data> type available in plists.

It has one attribute, *data*, that can be used to retrieve the Python string stored in it.

### 13.6.1 Examples

Generating a plist:

```
pl = dict(
    aString="Doodah",
    aList=["A", "B", 12, 32.1, [1, 2, 3]],
    aFloat = 0.1,
    anInt = 728,
    aDict=dict(
        anotherString("<hello & hi there!>"),
        aUnicodeValue=u'M\&#xe4;ssig, Ma\&#xdf',
        aTrueValue=True,
        aFalseValue=False,
    ),
    someData = Data("<binary gunk>"),
    someMoreData = Data("<lots of binary gunk>" * 10),
    aDate = datetime.datetime.fromtimestamp(time.mktime(time.gmtime())),
)
# unicode keys are possible, but a little awkward to use:
pl[u'\&#xc5;benraa'] = "That was a unicode key."
writePlist(pl, fileName)
```

Parsing a plist:

```
pl = readPlist(pathOrFile)
print pl["aKey"]
```

# CRYPTOGRAPHIC SERVICES

The modules described in this chapter implement various algorithms of a cryptographic nature. They are available at the discretion of the installation. Here's an overview:

## 14.1 `hashlib` — Secure hashes and message digests

New in version 2.5. **Source code:** `Lib/hashlib.py`

This module implements a common interface to many different secure hash and message digest algorithms. Included are the FIPS secure hash algorithms SHA1, SHA224, SHA256, SHA384, and SHA512 (defined in FIPS 180-2) as well as RSA's MD5 algorithm (defined in Internet [RFC 1321](#)). The terms secure hash and message digest are interchangeable. Older algorithms were called message digests. The modern term is secure hash.

**Note:** If you want the `adler32` or `crc32` hash functions they are available in the `zlib` module.

**Warning:** Some algorithms have known hash collision weaknesses, see the FAQ at the end.

There is one constructor method named for each type of *hash*. All return a hash object with the same simple interface. For example: use `sha1()` to create a SHA1 hash object. You can now feed this object with arbitrary strings using the `update()` method. At any point you can ask it for the *digest* of the concatenation of the strings fed to it so far using the `digest()` or `hexdigest()` methods.

Constructors for hash algorithms that are always present in this module are `md5()`, `sha1()`, `sha224()`, `sha256()`, `sha384()`, and `sha512()`. Additional algorithms may also be available depending upon the OpenSSL library that Python uses on your platform.

For example, to obtain the digest of the string 'Nobody inspects the spammish repetition':

```
>>> import hashlib
>>> m = hashlib.md5()
>>> m.update("Nobody inspects")
>>> m.update(" the spammish repetition")
>>> m.digest()
'\xbbd\x9c\x83\xdd\x1e\xa5\xc9\xd9\xde\xc9\xa1\x8d\xf0\xff\xe9'
>>> m.digest_size
16
>>> m.block_size
64
```

More condensed:

```
>>> hashlib.sha224("Nobody inspects the spammish repetition").hexdigest()
'a4337bc45a8fc544c03f52dc550cd6e1e87021bc896588bd79e901e2'
```

A generic `new()` constructor that takes the string name of the desired algorithm as its first parameter also exists to allow access to the above listed hashes as well as any other algorithms that your OpenSSL library may offer. The named constructors are much faster than `new()` and should be preferred.

Using `new()` with an algorithm provided by OpenSSL:

```
>>> h = hashlib.new('ripemd160')
>>> h.update("Nobody inspects the spammish repetition")
>>> h.hexdigest()
'cc4a5ce1b3df48aec5d22d1f16b894a0b894eccc'
```

This module provides the following constant attribute:

`hashlib.algorithms`

A tuple providing the names of the hash algorithms guaranteed to be supported by this module. New in version 2.7.

The following values are provided as constant attributes of the hash objects returned by the constructors:

`hash.digest_size`

The size of the resulting hash in bytes.

`hash.block_size`

The internal block size of the hash algorithm in bytes.

A hash object has the following methods:

`hash.update(arg)`

Update the hash object with the string `arg`. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b)`. Changed in version 2.7.

`hash.digest()`

Return the digest of the strings passed to the `update()` method so far. This is a string of `digest_size` bytes which may contain non-ASCII characters, including null bytes.

`hash.hexdigest()`

Like `digest()` except the digest is returned as a string of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

`hash.copy()`

Return a copy (“clone”) of the hash object. This can be used to efficiently compute the digests of strings that share a common initial substring.

**See Also:**

**Module `hmac`** A module to generate message authentication codes using hashes.

**Module `base64`** Another way to encode binary hashes for non-binary environments.

<http://csrc.nist.gov/publications/fips/fips180-2/fips180-2.pdf> The FIPS 180-2 publication on Secure Hash Algorithms.

[http://en.wikipedia.org/wiki/Cryptographic\\_hash\\_function#Cryptographic\\_hash\\_algorithms](http://en.wikipedia.org/wiki/Cryptographic_hash_function#Cryptographic_hash_algorithms) Wikipedia article with information on which algorithms have known issues and what that means regarding their use.

## 14.2 hmac — Keyed-Hashing for Message Authentication

New in version 2.2. **Source code:** [Lib/hmac.py](#)

This module implements the HMAC algorithm as described by [RFC 2104](#).

`hmac.new(key[, msg[, digestmod]])`

Return a new hmac object. If *msg* is present, the method call `update(msg)` is made. *digestmod* is the digest constructor or module for the HMAC object to use. It defaults to the `hashlib.md5()` constructor.

An HMAC object has the following methods:

`HMAC.update(msg)`

Update the hmac object with the string *msg*. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a + b)`.

`HMAC.digest()`

Return the digest of the strings passed to the `update()` method so far. This string will be the same length as the *digest\_size* of the digest given to the constructor. It may contain non-ASCII characters, including NUL bytes.

`HMAC.hexdigest()`

Like `digest()` except the digest is returned as a string twice the length containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

`HMAC.copy()`

Return a copy (“clone”) of the hmac object. This can be used to efficiently compute the digests of strings that share a common initial substring.

**See Also:**

**Module `hashlib`** The Python module providing secure hash functions.

## 14.3 md5 — MD5 message digest algorithm

Deprecated since version 2.5: Use the `hashlib` module instead. This module implements the interface to RSA’s MD5 message digest algorithm (see also Internet [RFC 1321](#)). Its use is quite straightforward: use `new()` to create an md5 object. You can now feed this object with arbitrary strings using the `update()` method, and at any point you can ask it for the *digest* (a strong kind of 128-bit checksum, a.k.a. “fingerprint”) of the concatenation of the strings fed to it so far using the `digest()` method.

For example, to obtain the digest of the string ‘Nobody inspects the spammish repetition’:

```
>>> import md5
>>> m = md5.new()
>>> m.update("Nobody inspects")
>>> m.update(" the spammish repetition")
>>> m.digest()
'\xbbd\x9c\x83\xdd\x1e\xa5\xc9\xd9\xde\xc9\xa1\x8d\xf0\xff\xe9'
```

More condensed:

```
>>> md5.new("Nobody inspects the spammish repetition").digest()
'\xbbd\x9c\x83\xdd\x1e\xa5\xc9\xd9\xde\xc9\xa1\x8d\xf0\xff\xe9'
```

The following values are provided as constants in the module and as attributes of the md5 objects returned by `new()`:

`md5.digest_size`

The size of the resulting digest in bytes. This is always 16.

The `md5` module provides the following functions:

`md5.new([arg])`

Return a new `md5` object. If `arg` is present, the method call `update(arg)` is made.

`md5.md5([arg])`

For backward compatibility reasons, this is an alternative name for the `new()` function.

An `md5` object has the following methods:

`md5.update(arg)`

Update the `md5` object with the string `arg`. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b)`.

`md5.digest()`

Return the digest of the strings passed to the `update()` method so far. This is a 16-byte string which may contain non-ASCII characters, including null bytes.

`md5.hexdigest()`

Like `digest()` except the digest is returned as a string of length 32, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

`md5.copy()`

Return a copy (“clone”) of the `md5` object. This can be used to efficiently compute the digests of strings that share a common initial substring.

**See Also:**

**Module `sha`** Similar module implementing the Secure Hash Algorithm (SHA). The SHA algorithm is considered a more secure hash.

## 14.4 sha — SHA-1 message digest algorithm

Deprecated since version 2.5: Use the `hashlib` module instead. This module implements the interface to NIST’s secure hash algorithm, known as SHA-1. SHA-1 is an improved version of the original SHA hash algorithm. It is used in the same way as the `md5` module: use `new()` to create an `sha` object, then feed this object with arbitrary strings using the `update()` method, and at any point you can ask it for the *digest* of the concatenation of the strings fed to it so far. SHA-1 digests are 160 bits instead of MD5’s 128 bits.

`sha.new([string])`

Return a new `sha` object. If `string` is present, the method call `update(string)` is made.

The following values are provided as constants in the module and as attributes of the `sha` objects returned by `new()`:

`sha.blocksize`

Size of the blocks fed into the hash function; this is always 1. This size is used to allow an arbitrary string to be hashed.

`sha.digest_size`

The size of the resulting digest in bytes. This is always 20.

An `sha` object has the same methods as `md5` objects:

`sha.update(arg)`

Update the `sha` object with the string `arg`. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b)`.

`sha.digest()`

Return the digest of the strings passed to the `update()` method so far. This is a 20-byte string which may contain non-ASCII characters, including null bytes.

`sha.hexdigest()`

Like `digest()` except the digest is returned as a string of length 40, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

`sha.copy()`

Return a copy (“clone”) of the sha object. This can be used to efficiently compute the digests of strings that share a common initial substring.

**See Also:**

**Secure Hash Standard** The Secure Hash Algorithm is defined by NIST document FIPS PUB 180-2: [Secure Hash Standard](#), published in August 2002.

**Cryptographic Toolkit (Secure Hashing)** [Links from NIST to various information on secure hashing.](#)

Hardcore cypherpunks will probably find the cryptographic modules written by A.M. Kuchling of further interest; the package contains modules for various encryption algorithms, most notably AES. These modules are not distributed with Python but available separately. See the URL <http://www.pycrypto.org> for more information.



# GENERIC OPERATING SYSTEM SERVICES

The modules described in this chapter provide interfaces to operating system features that are available on (almost) all operating systems, such as files and a clock. The interfaces are generally modeled after the Unix or C interfaces, but they are available on most other systems as well. Here's an overview:

## 15.1 `os` — Miscellaneous operating system interfaces

This module provides a portable way of using operating system dependent functionality. If you just want to read or write a file see `open()`, if you want to manipulate paths, see the `os.path` module, and if you want to read all the lines in all the files on the command line see the `fileinput` module. For creating temporary files and directories see the `tempfile` module, and for high-level file and directory handling see the `shutil` module.

Notes on the availability of these functions:

- The design of all built-in operating system dependent modules of Python is such that as long as the same functionality is available, it uses the same interface; for example, the function `os.stat(path)` returns stat information about *path* in the same format (which happens to have originated with the POSIX interface).
- Extensions peculiar to a particular operating system are also available through the `os` module, but using them is of course a threat to portability.
- An “Availability: Unix” note means that this function is commonly found on Unix systems. It does not make any claims about its existence on a specific operating system.
- If not separately noted, all functions that claim “Availability: Unix” are supported on Mac OS X, which builds on a Unix core.

---

**Note:** All functions in this module raise `OSError` in the case of invalid or inaccessible file names and paths, or other arguments that have the correct type, but are not accepted by the operating system.

---

### exception `os.error`

An alias for the built-in `OSError` exception.

### `os.name`

The name of the operating system dependent module imported. The following names have currently been registered: `'posix'`, `'nt'`, `'os2'`, `'ce'`, `'java'`, `'riscos'`.

### See Also:

`sys.platform` has a finer granularity. `os.uname()` gives system-dependent version information.

The `platform` module provides detailed checks for the system's identity.

### 15.1.1 Process Parameters

These functions and data items provide information and operate on the current process and user.

#### `os.environ`

A mapping object representing the string environment. For example, `environ['HOME']` is the pathname of your home directory (on some platforms), and is equivalent to `getenv("HOME")` in C.

This mapping is captured the first time the `os` module is imported, typically during Python startup as part of processing `site.py`. Changes to the environment made after this time are not reflected in `os.environ`, except for changes made by modifying `os.environ` directly.

If the platform supports the `putenv()` function, this mapping may be used to modify the environment as well as query the environment. `putenv()` will be called automatically when the mapping is modified.

---

**Note:** Calling `putenv()` directly does not change `os.environ`, so it's better to modify `os.environ`.

---

**Note:** On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for `putenv()`.

---

If `putenv()` is not provided, a modified copy of this mapping may be passed to the appropriate process-creation functions to cause child processes to use a modified environment.

If the platform supports the `unsetenv()` function, you can delete items in this mapping to unset environment variables. `unsetenv()` will be called automatically when an item is deleted from `os.environ`, and when one of the `pop()` or `clear()` methods is called. Changed in version 2.6: Also unset environment variables when calling `os.environ.clear()` and `os.environ.pop()`.

#### `os.chdir(path)`

#### `os.fchdir(fd)`

#### `os.getcwd()`

These functions are described in *Files and Directories*.

#### `os.ctermid()`

Return the filename corresponding to the controlling terminal of the process.

Availability: Unix.

#### `os.getegid()`

Return the effective group id of the current process. This corresponds to the “set id” bit on the file being executed in the current process.

Availability: Unix.

#### `os.geteuid()`

Return the current process's effective user id.

Availability: Unix.

#### `os.getgid()`

Return the real group id of the current process.

Availability: Unix.

#### `os.getgroups()`

Return list of supplemental group ids associated with the current process.

Availability: Unix.

---

**Note:** On Mac OS X, `getgroups()` behavior differs somewhat from other Unix platforms. If the Python interpreter was built with a deployment target of 10.5 or earlier, `getgroups()` returns the list of effective group ids associated with the current user process; this list is limited to a system-defined number of entries, typically 16, and may be modified by calls to `setgroups()` if suitably privileged. If built with a deployment target greater than 10.5, `getgroups()` returns the current group access list for the user associated with the effective user id of the process; the group access list may change over the lifetime of the process, it is not affected by calls to `setgroups()`, and its length is not limited to 16. The deployment target value, `MACOSX_DEPLOYMENT_TARGET`, can be obtained with `sysconfig.get_config_var()`.

---

**os.initgroups** (*username, gid*)

Call the system `initgroups()` to initialize the group access list with all of the groups of which the specified username is a member, plus the specified group id.

Availability: Unix. New in version 2.7.

**os.getlogin** ()

Return the name of the user logged in on the controlling terminal of the process. For most purposes, it is more useful to use the environment variable

`LOGNAME` to find out who the user is, or `pwd.getpwuid(os.getuid())[0]` to get the login name of the currently effective user id.

Availability: Unix.

**os.getpgid** (*pid*)

Return the process group id of the process with process id *pid*. If *pid* is 0, the process group id of the current process is returned.

Availability: Unix. New in version 2.3.

**os.getpgrp** ()

Return the id of the current process group.

Availability: Unix.

**os.getpid** ()

Return the current process id.

Availability: Unix, Windows.

**os.getppid** ()

Return the parent's process id.

Availability: Unix.

**os.getresuid** ()

Return a tuple (ruid, euid, suid) denoting the current process's real, effective, and saved user ids.

Availability: Unix. New in version 2.7.

**os.getresgid** ()

Return a tuple (rgid, egid, sgid) denoting the current process's real, effective, and saved group ids.

Availability: Unix. New in version 2.7.

**os.getuid** ()

Return the current process's user id.

Availability: Unix.

`os.getenv (varname[, value ])`  
Return the value of the environment variable *varname* if it exists, or *value* if it doesn't. *value* defaults to `None`.  
Availability: most flavors of Unix, Windows.

`os.putenv (varname, value)`  
Set the environment variable named *varname* to the string *value*. Such changes to the environment affect sub-processes started with `os.system()`, `popen()` or `fork()` and `execv()`.  
Availability: most flavors of Unix, Windows.

---

**Note:** On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for `putenv`.

---

When `putenv()` is supported, assignments to items in `os.environ` are automatically translated into corresponding calls to `putenv()`; however, calls to `putenv()` don't update `os.environ`, so it is actually preferable to assign to items of `os.environ`.

`os.setegid (egid)`  
Set the current process's effective group id.  
Availability: Unix.

`os.seteuid (euid)`  
Set the current process's effective user id.  
Availability: Unix.

`os.setgid (gid)`  
Set the current process' group id.  
Availability: Unix.

`os.setgroups (groups)`  
Set the list of supplemental group ids associated with the current process to *groups*. *groups* must be a sequence, and each element must be an integer identifying a group. This operation is typically available only to the superuser.  
Availability: Unix. New in version 2.2.

---

**Note:** On Mac OS X, the length of *groups* may not exceed the system-defined maximum number of effective group ids, typically 16. See the documentation for `getgroups()` for cases where it may not return the same group list set by calling `setgroups()`.

---

`os.setpgrp ()`  
Call the system call `setpgrp()` or `setpgrp(0, 0)()` depending on which version is implemented (if any). See the Unix manual for the semantics.  
Availability: Unix.

`os.setpgid (pid, grp)`  
Call the system call `setpgid()` to set the process group id of the process with id *pid* to the process group with id *grp*. See the Unix manual for the semantics.  
Availability: Unix.

`os.setregid (rgid, egid)`  
Set the current process's real and effective group ids.  
Availability: Unix.

- `os.setresgid` (*rgid, egid, sgid*)  
 Set the current process's real, effective, and saved group ids.  
 Availability: Unix. New in version 2.7.
- `os.setresuid` (*ruid, euid, suid*)  
 Set the current process's real, effective, and saved user ids.  
 Availability: Unix. New in version 2.7.
- `os.setreuid` (*ruid, euid*)  
 Set the current process's real and effective user ids.  
 Availability: Unix.
- `os.getsid` (*pid*)  
 Call the system call `getsid()`. See the Unix manual for the semantics.  
 Availability: Unix. New in version 2.4.
- `os.setsid` ()  
 Call the system call `setsid()`. See the Unix manual for the semantics.  
 Availability: Unix.
- `os.setuid` (*uid*)  
 Set the current process's user id.  
 Availability: Unix.
- `os.strerror` (*code*)  
 Return the error message corresponding to the error code in *code*. On platforms where `strerror()` returns NULL when given an unknown error number, `ValueError` is raised.  
 Availability: Unix, Windows.
- `os.umask` (*mask*)  
 Set the current numeric umask and return the previous umask.  
 Availability: Unix, Windows.
- `os.uname` ()  
 Return a 5-tuple containing information identifying the current operating system. The tuple contains 5 strings: (*sysname, nodename, release, version, machine*). Some systems truncate the *nodename* to 8 characters or to the leading component; a better way to get the hostname is `socket.gethostname()` or even `socket.gethostbyaddr(socket.gethostname())`.  
 Availability: recent flavors of Unix.
- `os.unsetenv` (*varname*)  
 Unset (delete) the environment variable named *varname*. Such changes to the environment affect subprocesses started with `os.system()`, `popen()` or `fork()` and `execv()`.  
 When `unsetenv()` is supported, deletion of items in `os.environ` is automatically translated into a corresponding call to `unsetenv()`; however, calls to `unsetenv()` don't update `os.environ`, so it is actually preferable to delete items of `os.environ`.  
 Availability: most flavors of Unix, Windows.

### 15.1.2 File Object Creation

These functions create new file objects. (See also `open()`.)

os.**fdopen** (*fd*[, *mode*[, *bufsize* ] ])

Return an open file object connected to the file descriptor *fd*. The *mode* and *bufsize* arguments have the same meaning as the corresponding arguments to the built-in `open()` function.

Availability: Unix, Windows. Changed in version 2.3: When specified, the *mode* argument must now start with one of the letters 'r', 'w', or 'a', otherwise a `ValueError` is raised. Changed in version 2.5: On Unix, when the *mode* argument starts with 'a', the `O_APPEND` flag is set on the file descriptor (which the `fdopen()` implementation already does on most platforms).

os.**popen** (*command*[, *mode*[, *bufsize* ] ])

Open a pipe to or from *command*. The return value is an open file object connected to the pipe, which can be read or written depending on whether *mode* is 'r' (default) or 'w'. The *bufsize* argument has the same meaning as the corresponding argument to the built-in `open()` function. The exit status of the command (encoded in the format specified for `wait()`) is available as the return value of the `close()` method of the file object, except that when the exit status is zero (termination without errors), `None` is returned.

Availability: Unix, Windows. Deprecated since version 2.6: This function is obsolete. Use the `subprocess` module. Check especially the *Replacing Older Functions with the subprocess Module* section. Changed in version 2.0: This function worked unreliably under Windows in earlier versions of Python. This was due to the use of the `_popen()` function from the libraries provided with Windows. Newer versions of Python do not use the broken implementation from the Windows libraries.

os.**tmpfile** ()

Return a new file object opened in update mode (`w+b`). The file has no directory entries associated with it and will be automatically deleted once there are no file descriptors for the file.

Availability: Unix, Windows.

There are a number of different `popen*` () functions that provide slightly different ways to create subprocesses. Deprecated since version 2.6: All of the `popen*` () functions are obsolete. Use the `subprocess` module. For each of the `popen*` () variants, if *bufsize* is specified, it specifies the buffer size for the I/O pipes. *mode*, if provided, should be the string 'b' or 't'; on Windows this is needed to determine whether the file objects should be opened in binary or text mode. The default value for *mode* is 't'.

Also, for each of these variants, on Unix, *cmd* may be a sequence, in which case arguments will be passed directly to the program without shell intervention (as with `os.spawnv()`). If *cmd* is a string it will be passed to the shell (as with `os.system()`).

These methods do not make it possible to retrieve the exit status from the child processes. The only way to control the input and output streams and also retrieve the return codes is to use the `subprocess` module; these are only available on Unix.

For a discussion of possible deadlock conditions related to the use of these functions, see *Flow Control Issues*.

os.**popen2** (*cmd*[, *mode*[, *bufsize* ] ])

Execute *cmd* as a sub-process and return the file objects (`child_stdin`, `child_stdout`). Deprecated since version 2.6: This function is obsolete. Use the `subprocess` module. Check especially the *Replacing Older Functions with the subprocess Module* section. Availability: Unix, Windows. New in version 2.0.

os.**popen3** (*cmd*[, *mode*[, *bufsize* ] ])

Execute *cmd* as a sub-process and return the file objects (`child_stdin`, `child_stdout`, `child_stderr`). Deprecated since version 2.6: This function is obsolete. Use the `subprocess` module. Check especially the *Replacing Older Functions with the subprocess Module* section. Availability: Unix, Windows. New in version 2.0.

os.**popen4** (*cmd*[, *mode*[, *bufsize* ] ])

Execute *cmd* as a sub-process and return the file objects (`child_stdin`, `child_stdout_and_stderr`). Deprecated since version 2.6: This function is obsolete. Use the `subprocess` module. Check especially the *Replacing Older Functions with the subprocess Module* section. Availability: Unix, Windows. New in version 2.0.

(Note that `child_stdin`, `child_stdout`, and `child_stderr` are named from the point of view of the child process, so `child_stdin` is the child's standard input.)

This functionality is also available in the `popen2` module using functions of the same names, but the return values of those functions have a different order.

### 15.1.3 File Descriptor Operations

These functions operate on I/O streams referenced using file descriptors.

File descriptors are small integers corresponding to a file that has been opened by the current process. For example, standard input is usually file descriptor 0, standard output is 1, and standard error is 2. Further files opened by a process will then be assigned 3, 4, 5, and so forth. The name “file descriptor” is slightly deceptive; on Unix platforms, sockets and pipes are also referenced by file descriptors.

The `fileno()` method can be used to obtain the file descriptor associated with a file object when required. Note that using the file descriptor directly will bypass the file object methods, ignoring aspects such as internal buffering of data.

`os.close(fd)`

Close file descriptor *fd*.

Availability: Unix, Windows.

---

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by `os.open()` or `pipe()`. To close a “file object” returned by the built-in function `open()` or by `popen()` or `fdopen()`, use its `close()` method.

---

`os.closerange(fd_low, fd_high)`

Close all file descriptors from *fd\_low* (inclusive) to *fd\_high* (exclusive), ignoring errors. Equivalent to:

```
for fd in xrange(fd_low, fd_high):
    try:
        os.close(fd)
    except OSError:
        pass
```

Availability: Unix, Windows. New in version 2.6.

`os.dup(fd)`

Return a duplicate of file descriptor *fd*.

Availability: Unix, Windows.

`os.dup2(fd, fd2)`

Duplicate file descriptor *fd* to *fd2*, closing the latter first if necessary.

Availability: Unix, Windows.

`os.fchmod(fd, mode)`

Change the mode of the file given by *fd* to the numeric *mode*. See the docs for `chmod()` for possible values of *mode*.

Availability: Unix. New in version 2.6.

`os.fchown(fd, uid, gid)`

Change the owner and group id of the file given by *fd* to the numeric *uid* and *gid*. To leave one of the ids unchanged, set it to -1.

Availability: Unix. New in version 2.6.

os.**fdatasync** (*fd*)

Force write of file with filedescriptor *fd* to disk. Does not force update of metadata.

Availability: Unix.

---

**Note:** This function is not available on MacOS.

---

os.**fpathconf** (*fd*, *name*)

Return system configuration information relevant to an open file. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the `pathconf_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If *name* is a string and is not known, `ValueError` is raised. If a specific value for *name* is not supported by the host system, even if it is included in `pathconf_names`, an `OSError` is raised with `errno.EINVAL` for the error number.

Availability: Unix.

os.**fstat** (*fd*)

Return status for file descriptor *fd*, like `stat()`.

Availability: Unix, Windows.

os.**fstatvfs** (*fd*)

Return information about the filesystem containing the file associated with file descriptor *fd*, like `statvfs()`.

Availability: Unix.

os.**fsync** (*fd*)

Force write of file with filedescriptor *fd* to disk. On Unix, this calls the native `fsync()` function; on Windows, the `MS_commit()` function.

If you're starting with a Python file object *f*, first do `f.flush()`, and then do `os.fsync(f.fileno())`, to ensure that all internal buffers associated with *f* are written to disk.

Availability: Unix, and Windows starting in 2.2.3.

os.**ftruncate** (*fd*, *length*)

Truncate the file corresponding to file descriptor *fd*, so that it is at most *length* bytes in size.

Availability: Unix.

os.**isatty** (*fd*)

Return `True` if the file descriptor *fd* is open and connected to a tty(-like) device, else `False`.

Availability: Unix.

os.**lseek** (*fd*, *pos*, *how*)

Set the current position of file descriptor *fd* to position *pos*, modified by *how*: `SEEK_SET` or 0 to set the position relative to the beginning of the file; `SEEK_CUR` or 1 to set it relative to the current position; `os.SEEK_END` or 2 to set it relative to the end of the file.

Availability: Unix, Windows.

os.**SEEK\_SET**

os.**SEEK\_CUR**

os.**SEEK\_END**

Parameters to the `lseek()` function. Their values are 0, 1, and 2, respectively.

Availability: Windows, Unix. New in version 2.5.

**os.open** (*file*, *flags* [, *mode* ])

Open the file *file* and set various flags according to *flags* and possibly its mode according to *mode*. The default *mode* is 0777 (octal), and the current umask value is first masked out. Return the file descriptor for the newly opened file.

For a description of the flag and mode values, see the C run-time documentation; flag constants (like `O_RDONLY` and `O_WRONLY`) are defined in this module too (see *open() flag constants*). In particular, on Windows adding `O_BINARY` is needed to open files in binary mode.

Availability: Unix, Windows.

---

**Note:** This function is intended for low-level I/O. For normal usage, use the built-in function `open()`, which returns a “file object” with `read()` and `write()` methods (and many more). To wrap a file descriptor in a “file object”, use `fdopen()`.

---

**os.openpty** ()

Open a new pseudo-terminal pair. Return a pair of file descriptors (*master*, *slave*) for the pty and the tty, respectively. For a (slightly) more portable approach, use the `pty` module.

Availability: some flavors of Unix.

**os.pipe** ()

Create a pipe. Return a pair of file descriptors (*r*, *w*) usable for reading and writing, respectively.

Availability: Unix, Windows.

**os.read** (*fd*, *n*)

Read at most *n* bytes from file descriptor *fd*. Return a string containing the bytes read. If the end of the file referred to by *fd* has been reached, an empty string is returned.

Availability: Unix, Windows.

---

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by `os.open()` or `pipe()`. To read a “file object” returned by the built-in function `open()` or by `popen()` or `fdopen()`, or `sys.stdin`, use its `read()` or `readline()` methods.

---

**os.tcgetpgrp** (*fd*)

Return the process group associated with the terminal given by *fd* (an open file descriptor as returned by `os.open()`).

Availability: Unix.

**os.tcsetpgrp** (*fd*, *pg*)

Set the process group associated with the terminal given by *fd* (an open file descriptor as returned by `os.open()`) to *pg*.

Availability: Unix.

**os.ttyname** (*fd*)

Return a string which specifies the terminal device associated with file descriptor *fd*. If *fd* is not associated with a terminal device, an exception is raised.

Availability: Unix.

**os.write** (*fd*, *str*)

Write the string *str* to file descriptor *fd*. Return the number of bytes actually written.

Availability: Unix, Windows.

---

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by `os.open()` or `pipe()`. To write a “file object” returned by the built-in function `open()` or by `popen()` or `fdopen()`, or `sys.stdout` or `sys.stderr`, use its `write()` method.

---

### `open()` flag constants

The following constants are options for the *flags* parameter to the `open()` function. They can be combined using the bitwise OR operator `|`. Some of them are not available on all platforms. For descriptions of their availability and use, consult the *open(2)* manual page on Unix or [the MSDN](#) on Windows.

```
os.O_RDONLY
os.O_WRONLY
os.O_RDWR
os.O_APPEND
os.O_CREAT
os.O_EXCL
os.O_TRUNC
```

These constants are available on Unix and Windows.

```
os.O_DSYNC
os.O_RSYNC
os.O_SYNC
os.O_NDELAY
os.O_NONBLOCK
os.O_NOCTTY
os.O_SHLOCK
os.O_EXLOCK
```

These constants are only available on Unix.

```
os.O_BINARY
os.O_NOINHERIT
os.O_SHORT_LIVED
os.O_TEMPORARY
os.O_RANDOM
os.O_SEQUENTIAL
os.O_TEXT
```

These constants are only available on Windows.

```
os.O_ASYNC
os.O_DIRECT
os.O_DIRECTORY
os.O_NOFOLLOW
os.O_NOATIME
```

These constants are GNU extensions and not present if they are not defined by the C library.

## 15.1.4 Files and Directories

`os.access(path, mode)`

Use the real uid/gid to test for access to *path*. Note that most operations will use the effective uid/gid, therefore this routine can be used in a `suid/sgid` environment to test if the invoking user has the specified access to *path*. *mode* should be `F_OK` to test the existence of *path*, or it can be the inclusive OR of one or more of `R_OK`,

`W_OK`, and `X_OK` to test permissions. Return `True` if access is allowed, `False` if not. See the Unix man page `access(2)` for more information.

Availability: Unix, Windows.

**Note:** Using `access()` to check if a user is authorized to e.g. open a file before actually doing so using `open()` creates a security hole, because the user might exploit the short time interval between checking and opening the file to manipulate it. It's preferable to use *EAFP* techniques. For example:

```
if os.access("myfile", os.R_OK):
    with open("myfile") as fp:
        return fp.read()
return "some default data"
```

is better written as:

```
try:
    fp = open("myfile")
except IOError as e:
    if e.errno == errno.EACCES:
        return "some default data"
    # Not a permission error.
    raise
else:
    with fp:
        return fp.read()
```

**Note:** I/O operations may fail even when `access()` indicates that they would succeed, particularly for operations on network filesystems which may have permissions semantics beyond the usual POSIX permission-bit model.

#### `os.F_OK`

Value to pass as the *mode* parameter of `access()` to test the existence of *path*.

#### `os.R_OK`

Value to include in the *mode* parameter of `access()` to test the readability of *path*.

#### `os.W_OK`

Value to include in the *mode* parameter of `access()` to test the writability of *path*.

#### `os.X_OK`

Value to include in the *mode* parameter of `access()` to determine if *path* can be executed.

#### `os.chdir(path)`

Change the current working directory to *path*.

Availability: Unix, Windows.

#### `os.fchdir(fd)`

Change the current working directory to the directory represented by the file descriptor *fd*. The descriptor must refer to an opened directory, not an open file.

Availability: Unix. New in version 2.3.

#### `os.getcwd()`

Return a string representing the current working directory.

Availability: Unix, Windows.

os.**getcwdu** ()

Return a Unicode object representing the current working directory.

Availability: Unix, Windows. New in version 2.3.

os.**chflags** (*path*, *flags*)

Set the flags of *path* to the numeric *flags*. *flags* may take a combination (bitwise OR) of the following values (as defined in the `stat` module):

- `stat.UF_NODUMP`
- `stat.UF_IMMUTABLE`
- `stat.UF_APPEND`
- `stat.UF_OPAQUE`
- `stat.UF_NOUNLINK`
- `stat.UF_COMPRESSED`
- `stat.UF_HIDDEN`
- `stat.SF_ARCHIVED`
- `stat.SF_IMMUTABLE`
- `stat.SF_APPEND`
- `stat.SF_NOUNLINK`
- `stat.SF_SNAPSHOT`

Availability: Unix. New in version 2.6.

os.**chroot** (*path*)

Change the root directory of the current process to *path*. Availability: Unix. New in version 2.2.

os.**chmod** (*path*, *mode*)

Change the mode of *path* to the numeric *mode*. *mode* may take one of the following values (as defined in the `stat` module) or bitwise ORed combinations of them:

- `stat.S_ISUID`
- `stat.S_ISGID`
- `stat.S_ENFMT`
- `stat.S_ISVTX`
- `stat.S_IREAD`
- `stat.S_IWRITE`
- `stat.S_IEXEC`
- `stat.S_IRWXU`
- `stat.S_IRUSR`
- `stat.S_IWUSR`
- `stat.S_IXUSR`
- `stat.S_IRWXG`
- `stat.S_IRGRP`

- `stat.S_IWGRP`
- `stat.S_IXGRP`
- `stat.S_IRWXO`
- `stat.S_IROTH`
- `stat.S_IWOTH`
- `stat.S_IXOTH`

Availability: Unix, Windows.

---

**Note:** Although Windows supports `chmod()`, you can only set the file’s read-only flag with it (via the `stat.S_IWRITE` and `stat.S_IREAD` constants or a corresponding integer value). All other bits are ignored.

---

- os.**chown** (*path*, *uid*, *gid*)  
Change the owner and group id of *path* to the numeric *uid* and *gid*. To leave one of the ids unchanged, set it to `-1`.  
Availability: Unix.
- os.**lchflags** (*path*, *flags*)  
Set the flags of *path* to the numeric *flags*, like `chflags()`, but do not follow symbolic links.  
Availability: Unix. New in version 2.6.
- os.**lchmod** (*path*, *mode*)  
Change the mode of *path* to the numeric *mode*. If *path* is a symlink, this affects the symlink rather than the target. See the docs for `chmod()` for possible values of *mode*.  
Availability: Unix. New in version 2.6.
- os.**lchown** (*path*, *uid*, *gid*)  
Change the owner and group id of *path* to the numeric *uid* and *gid*. This function will not follow symbolic links.  
Availability: Unix. New in version 2.3.
- os.**link** (*source*, *link\_name*)  
Create a hard link pointing to *source* named *link\_name*.  
Availability: Unix.
- os.**listdir** (*path*)  
Return a list containing the names of the entries in the directory given by *path*. The list is in arbitrary order. It does not include the special entries `'.'` and `'..'` even if they are present in the directory.  
Availability: Unix, Windows. Changed in version 2.3: On Windows NT/2k/XP and Unix, if *path* is a Unicode object, the result will be a list of Unicode objects. Undecodable filenames will still be returned as string objects.
- os.**lstat** (*path*)  
Perform the equivalent of an `lstat()` system call on the given path. Similar to `stat()`, but does not follow symbolic links. On platforms that do not support symbolic links, this is an alias for `stat()`.
- os.**mkfifo** (*path*[, *mode*])  
Create a FIFO (a named pipe) named *path* with numeric mode *mode*. The default *mode* is `0666` (octal). The current umask value is first masked out from the mode.  
Availability: Unix.  
FIFOs are pipes that can be accessed like regular files. FIFOs exist until they are deleted (for example with `os.unlink()`). Generally, FIFOs are used as rendezvous between “client” and “server” type processes: the

server opens the FIFO for reading, and the client opens it for writing. Note that `mkfifo()` doesn't open the FIFO — it just creates the rendezvous point.

os.**mknod**(*filename*[, *mode*=0600[, *device*=0]])

Create a filesystem node (file, device special file or named pipe) named *filename*. *mode* specifies both the permissions to use and the type of node to be created, being combined (bitwise OR) with one of `stat.S_IFREG`, `stat.S_IFCHR`, `stat.S_IFBLK`, and `stat.S_IFIFO` (those constants are available in `stat`). For `stat.S_IFCHR` and `stat.S_IFBLK`, *device* defines the newly created device special file (probably using `os.makedev()`), otherwise it is ignored. New in version 2.3.

os.**major**(*device*)

Extract the device major number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`). New in version 2.3.

os.**minor**(*device*)

Extract the device minor number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`). New in version 2.3.

os.**makedev**(*major*, *minor*)

Compose a raw device number from the major and minor device numbers. New in version 2.3.

os.**mkdir**(*path*[, *mode*])

Create a directory named *path* with numeric mode *mode*. The default *mode* is 0777 (octal). On some systems, *mode* is ignored. Where it is used, the current umask value is first masked out. If the directory already exists, `OSError` is raised.

It is also possible to create temporary directories; see the `tempfile` module's `tempfile.mkdtemp()` function.

Availability: Unix, Windows.

os.**makedirs**(*path*[, *mode*])

Recursive directory creation function. Like `mkdir()`, but makes all intermediate-level directories needed to contain the leaf directory. Raises an `error` exception if the leaf directory already exists or cannot be created. The default *mode* is 0777 (octal). On some systems, *mode* is ignored. Where it is used, the current umask value is first masked out.

---

**Note:** `makedirs()` will become confused if the path elements to create include `os.pardir`.

---

New in version 1.5.2.Changed in version 2.3: This function now handles UNC paths correctly.

os.**pathconf**(*path*, *name*)

Return system configuration information relevant to a named file. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the `pathconf_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If *name* is a string and is not known, `ValueError` is raised. If a specific value for *name* is not supported by the host system, even if it is included in `pathconf_names`, an `OSError` is raised with `errno.EINVAL` for the error number.

Availability: Unix.

os.**pathconf\_names**

Dictionary mapping names accepted by `pathconf()` and `fpathconf()` to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system. Availability: Unix.

**os.readlink** (*path*)

Return a string representing the path to which the symbolic link points. The result may be either an absolute or relative pathname; if it is relative, it may be converted to an absolute pathname using `os.path.join(os.path.dirname(path), result)`. Changed in version 2.6: If the *path* is a Unicode object the result will also be a Unicode object. Availability: Unix.

**os.remove** (*path*)

Remove (delete) the file *path*. If *path* is a directory, `OSError` is raised; see `rmdir()` below to remove a directory. This is identical to the `unlink()` function documented below. On Windows, attempting to remove a file that is in use causes an exception to be raised; on Unix, the directory entry is removed but the storage allocated to the file is not made available until the original file is no longer in use.

Availability: Unix, Windows.

**os.removedirs** (*path*)

Remove directories recursively. Works like `rmdir()` except that, if the leaf directory is successfully removed, `removedirs()` tries to successively remove every parent directory mentioned in *path* until an error is raised (which is ignored, because it generally means that a parent directory is not empty). For example, `os.removedirs('foo/bar/baz')` will first remove the directory `'foo/bar/baz'`, and then remove `'foo/bar'` and `'foo'` if they are empty. Raises `OSError` if the leaf directory could not be successfully removed. New in version 1.5.2.

**os.rename** (*src, dst*)

Rename the file or directory *src* to *dst*. If *dst* is a directory, `OSError` will be raised. On Unix, if *dst* exists and is a file, it will be replaced silently if the user has permission. The operation may fail on some Unix flavors if *src* and *dst* are on different filesystems. If successful, the renaming will be an atomic operation (this is a POSIX requirement). On Windows, if *dst* already exists, `OSError` will be raised even if it is a file; there may be no way to implement an atomic rename when *dst* names an existing file.

Availability: Unix, Windows.

**os.rename** (*old, new*)

Recursive directory or file renaming function. Works like `rename()`, except creation of any intermediate directories needed to make the new pathname good is attempted first. After the rename, directories corresponding to rightmost path segments of the old name will be pruned away using `removedirs()`. New in version 1.5.2.

---

**Note:** This function can fail with the new directory structure made if you lack permissions needed to remove the leaf directory or file.

---

**os.rmdir** (*path*)

Remove (delete) the directory *path*. Only works when the directory is empty, otherwise, `OSError` is raised. In order to remove whole directory trees, `shutil.rmtree()` can be used.

Availability: Unix, Windows.

**os.stat** (*path*)

Perform the equivalent of a `stat()` system call on the given path. (This function follows symlinks; to stat a symlink use `lstat()`.)

The return value is an object whose attributes correspond to the members of the `stat` structure, namely:

- `st_mode` - protection bits,
- `st_ino` - inode number,
- `st_dev` - device,
- `st_nlink` - number of hard links,
- `st_uid` - user id of owner,

- `st_gid` - group id of owner,
- `st_size` - size of file, in bytes,
- `st_atime` - time of most recent access,
- `st_mtime` - time of most recent content modification,
- `st_ctime` - platform dependent; time of most recent metadata change on Unix, or the time of creation on Windows)

Changed in version 2.3: If `stat_float_times()` returns `True`, the time values are floats, measuring seconds. Fractions of a second may be reported if the system supports that. On Mac OS, the times are always floats. See `stat_float_times()` for further discussion. On some Unix systems (such as Linux), the following attributes may also be available:

- `st_blocks` - number of blocks allocated for file
- `st_blksize` - filesystem blocksize
- `st_rdev` - type of device if an inode device
- `st_flags` - user defined flags for file

On other Unix systems (such as FreeBSD), the following attributes may be available (but may be only filled out if root tries to use them):

- `st_gen` - file generation number
- `st_birthtime` - time of file creation

On Mac OS systems, the following attributes may also be available:

- `st_rsize`
- `st_creator`
- `st_type`

On RISCOS systems, the following attributes are also available:

- `st_fstype` (file type)
- `st_attrs` (attributes)
- `st_obtype` (object type).

---

**Note:** The exact meaning and resolution of the `st_atime`, `st_mtime`, and `st_ctime` attributes depend on the operating system and the file system. For example, on Windows systems using the FAT or FAT32 file systems, `st_mtime` has 2-second resolution, and `st_atime` has only 1-day resolution. See your operating system documentation for details.

---

For backward compatibility, the return value of `stat()` is also accessible as a tuple of at least 10 integers giving the most important (and portable) members of the `stat` structure, in the order `st_mode`, `st_ino`, `st_dev`, `st_nlink`, `st_uid`, `st_gid`, `st_size`, `st_atime`, `st_mtime`, `st_ctime`. More items may be added at the end by some implementations.

The standard module `stat` defines functions and constants that are useful for extracting information from a `stat` structure. (On Windows, some items are filled with dummy values.)

Example:

```
>>> import os
>>> statinfo = os.stat('somefile.txt')
```

```
>>> statinfo
(33188, 422511, 769, 1, 1032, 100, 926, 1105022698, 1105022732, 1105022732)
>>> statinfo.st_size
926
```

Availability: Unix, Windows. Changed in version 2.2: Added access to values as attributes of the returned object. Changed in version 2.5: Added `st_gen` and `st_birthtime`.

**os.stat\_float\_times** (*[newvalue]*)

Determine whether `stat_result` represents time stamps as float objects. If *newvalue* is `True`, future calls to `stat()` return floats, if it is `False`, future calls return ints. If *newvalue* is omitted, return the current setting.

For compatibility with older Python versions, accessing `stat_result` as a tuple always returns integers. Changed in version 2.5: Python now returns float values by default. Applications which do not work correctly with floating point time stamps can use this function to restore the old behaviour. The resolution of the timestamps (that is the smallest possible fraction) depends on the system. Some systems only support second resolution; on these systems, the fraction will always be zero.

It is recommended that this setting is only changed at program startup time in the `__main__` module; libraries should never change this setting. If an application uses a library that works incorrectly if floating point time stamps are processed, this application should turn the feature off until the library has been corrected.

**os.statvfs** (*path*)

Perform a `statvfs()` system call on the given path. The return value is an object whose attributes describe the filesystem on the given path, and correspond to the members of the `statvfs` structure, namely: `f_bsize`, `f_frsize`, `f_blocks`, `f_bfree`, `f_bavail`, `f_files`, `f_ffree`, `f_favail`, `f_flag`, `f_namemax`.

For backward compatibility, the return value is also accessible as a tuple whose values correspond to the attributes, in the order given above. The standard module `statvfs` defines constants that are useful for extracting information from a `statvfs` structure when accessing it as a sequence; this remains useful when writing code that needs to work with versions of Python that don't support accessing the fields as attributes.

Availability: Unix. Changed in version 2.2: Added access to values as attributes of the returned object.

**os.symlink** (*source*, *link\_name*)

Create a symbolic link pointing to *source* named *link\_name*.

Availability: Unix.

**os.tempnam** (*[dir*, *prefix]*)

Return a unique path name that is reasonable for creating a temporary file. This will be an absolute path that names a potential directory entry in the directory *dir* or a common location for temporary files if *dir* is omitted or `None`. If given and not `None`, *prefix* is used to provide a short prefix to the filename. Applications are responsible for properly creating and managing files created using paths returned by `tempnam()`; no automatic cleanup is provided. On Unix, the environment variable `TMPDIR` overrides *dir*, while on Windows `TMP` is used. The specific behavior of this function depends on the C library implementation; some aspects are underspecified in system documentation.

**Warning:** Use of `tempnam()` is vulnerable to symlink attacks; consider using `tempfile()` (section [File Object Creation](#)) instead.

Availability: Unix, Windows.

**os.tmpnam** ()

Return a unique path name that is reasonable for creating a temporary file. This will be an absolute path that names a potential directory entry in a common location for temporary files. Applications are responsible for properly creating and managing files created using paths returned by `tmpnam()`; no automatic cleanup is provided.

**Warning:** Use of `tmpnam()` is vulnerable to symlink attacks; consider using `tmpfile()` (section *File Object Creation*) instead.

Availability: Unix, Windows. This function probably shouldn't be used on Windows, though: Microsoft's implementation of `tmpnam()` always creates a name in the root directory of the current drive, and that's generally a poor location for a temp file (depending on privileges, you may not even be able to open a file using this name).

os.**TMP\_MAX**

The maximum number of unique names that `tmpnam()` will generate before reusing names.

os.**unlink** (*path*)

Remove (delete) the file *path*. This is the same function as `remove()`; the `unlink()` name is its traditional Unix name.

Availability: Unix, Windows.

os.**utime** (*path*, *times*)

Set the access and modified times of the file specified by *path*. If *times* is `None`, then the file's access and modified times are set to the current time. (The effect is similar to running the Unix program **touch** on the path.) Otherwise, *times* must be a 2-tuple of numbers, of the form (*atime*, *mtime*) which is used to set the access and modified times, respectively. Whether a directory can be given for *path* depends on whether the operating system implements directories as files (for example, Windows does not). Note that the exact times you set here may not be returned by a subsequent `stat()` call, depending on the resolution with which your operating system records access and modification times; see `stat()`. Changed in version 2.0: Added support for `None` for *times*. Availability: Unix, Windows.

os.**walk** (*top*, *topdown=True*, *onerror=None*, *followlinks=False*)

Generate the file names in a directory tree by walking the tree either top-down or bottom-up. For each directory in the tree rooted at directory *top* (including *top* itself), it yields a 3-tuple (*dirpath*, *dirnames*, *filenames*).

*dirpath* is a string, the path to the directory. *dirnames* is a list of the names of the subdirectories in *dirpath* (excluding `'.'` and `'..'`). *filenames* is a list of the names of the non-directory files in *dirpath*. Note that the names in the lists contain no path components. To get a full path (which begins with *top*) to a file or directory in *dirpath*, do `os.path.join(dirpath, name)`.

If optional argument *topdown* is `True` or not specified, the triple for a directory is generated before the triples for any of its subdirectories (directories are generated top-down). If *topdown* is `False`, the triple for a directory is generated after the triples for all of its subdirectories (directories are generated bottom-up).

When *topdown* is `True`, the caller can modify the *dirnames* list in-place (perhaps using `del` or slice assignment), and `walk()` will only recurse into the subdirectories whose names remain in *dirnames*; this can be used to prune the search, impose a specific order of visiting, or even to inform `walk()` about directories the caller creates or renames before it resumes `walk()` again. Modifying *dirnames* when *topdown* is `False` is ineffective, because in bottom-up mode the directories in *dirnames* are generated before *dirpath* itself is generated.

By default, errors from the `listdir()` call are ignored. If optional argument *onerror* is specified, it should be a function; it will be called with one argument, an `OSError` instance. It can report the error to continue with the walk, or raise the exception to abort the walk. Note that the filename is available as the *filename* attribute of the exception object.

By default, `walk()` will not walk down into symbolic links that resolve to directories. Set *followlinks* to `True` to visit directories pointed to by symlinks, on systems that support them. New in version 2.6: The *followlinks* parameter.

---

**Note:** Be aware that setting *followlinks* to `True` can lead to infinite recursion if a link points to a parent directory of itself. `walk()` does not keep track of the directories it visited already.

---

**Note:** If you pass a relative pathname, don't change the current working directory between resumptions of `walk()`. `walk()` never changes the current directory, and assumes that its caller doesn't either.

---

This example displays the number of bytes taken by non-directory files in each directory under the starting directory, except that it doesn't look under any CVS subdirectory:

```
import os
from os.path import join, getsize
for root, dirs, files in os.walk('python/Lib/email'):
    print root, "consumes",
    print sum(getsize(join(root, name)) for name in files),
    print "bytes in", len(files), "non-directory files"
    if 'CVS' in dirs:
        dirs.remove('CVS') # don't visit CVS directories
```

In the next example, walking the tree bottom-up is essential: `rmdir()` doesn't allow deleting a directory before the directory is empty:

```
# Delete everything reachable from the directory named in "top",
# assuming there are no symbolic links.
# CAUTION: This is dangerous! For example, if top == '/', it
# could delete all your disk files.
import os
for root, dirs, files in os.walk(top, topdown=False):
    for name in files:
        os.remove(os.path.join(root, name))
    for name in dirs:
        os.rmdir(os.path.join(root, name))
```

New in version 2.3.

## 15.1.5 Process Management

These functions may be used to create and manage processes.

The various `exec*`() functions take a list of arguments for the new program loaded into the process. In each case, the first of these arguments is passed to the new program as its own name rather than as an argument a user may have typed on a command line. For the C programmer, this is the `argv[0]` passed to a program's `main()`. For example, `os.execv('/bin/echo', ['foo', 'bar'])` will only print `bar` on standard output; `foo` will seem to be ignored.

`os.abort()`

Generate a SIGABRT signal to the current process. On Unix, the default behavior is to produce a core dump; on Windows, the process immediately returns an exit code of 3. Be aware that calling this function will not call the Python signal handler registered for SIGABRT with `signal.signal()`.

Availability: Unix, Windows.

```
os.execl(path, arg0, arg1, ...)
os.execlp(path, arg0, arg1, ..., env)
os.execlp(file, arg0, arg1, ...)
os.execlpe(file, arg0, arg1, ..., env)
os.execv(path, args)
```

`os.execve(path, args, env)`

`os.execvp(file, args)`

`os.execvpe(file, args, env)`

These functions all execute a new program, replacing the current process; they do not return. On Unix, the new executable is loaded into the current process, and will have the same process id as the caller. Errors will be reported as `OSError` exceptions.

The current process is replaced immediately. Open file objects and descriptors are not flushed, so if there may be data buffered on these open files, you should flush them using `sys.stdout.flush()` or `os.fsync()` before calling an `exec*()` function.

The “l” and “v” variants of the `exec*()` functions differ in how command-line arguments are passed. The “l” variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the `execl*()` functions. The “v” variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the `args` parameter. In either case, the arguments to the child process should start with the name of the command being run, but this is not enforced.

The variants which include a “p” near the end (`execlp()`, `execlpe()`, `execvp()`, and `execvpe()`) will use the

`PATH` environment variable to locate the program `file`. When the environment is being replaced (using one of the `exec*e()` variants, discussed in the next paragraph), the new environment is used as the source of the `PATH` variable. The other variants, `execl()`, `execlpe()`, `execv()`, and `execve()`, will not use the `PATH` variable to locate the executable; `path` must contain an appropriate absolute or relative path.

For `execlpe()`, `execvpe()`, and `execvpe()` (note that these all end in “e”), the `env` parameter must be a mapping which is used to define the environment variables for the new process (these are used instead of the current process’ environment); the functions `execl()`, `execlp()`, `execv()`, and `execvp()` all cause the new process to inherit the environment of the current process.

Availability: Unix, Windows.

`os._exit(n)`

Exit the process with status `n`, without calling cleanup handlers, flushing stdio buffers, etc.

Availability: Unix, Windows.

---

**Note:** The standard way to exit is `sys.exit(n)`. `_exit()` should normally only be used in the child process after a `fork()`.

---

The following exit codes are defined and can be used with `_exit()`, although they are not required. These are typically used for system programs written in Python, such as a mail server’s external command delivery program.

---

**Note:** Some of these may not be available on all Unix platforms, since there is some variation. These constants are defined where they are defined by the underlying platform.

---

`os.EX_OK`

Exit code that means no error occurred.

Availability: Unix. New in version 2.3.

`os.EX_USAGE`

Exit code that means the command was used incorrectly, such as when the wrong number of arguments are given.

Availability: Unix. New in version 2.3.

- os.**EX\_DATAERR**  
Exit code that means the input data was incorrect.  
Availability: Unix. New in version 2.3.
- os.**EX\_NOINPUT**  
Exit code that means an input file did not exist or was not readable.  
Availability: Unix. New in version 2.3.
- os.**EX\_NOUSER**  
Exit code that means a specified user did not exist.  
Availability: Unix. New in version 2.3.
- os.**EX\_NOHOST**  
Exit code that means a specified host did not exist.  
Availability: Unix. New in version 2.3.
- os.**EX\_UNAVAILABLE**  
Exit code that means that a required service is unavailable.  
Availability: Unix. New in version 2.3.
- os.**EX\_SOFTWARE**  
Exit code that means an internal software error was detected.  
Availability: Unix. New in version 2.3.
- os.**EX\_OSERR**  
Exit code that means an operating system error was detected, such as the inability to fork or create a pipe.  
Availability: Unix. New in version 2.3.
- os.**EX\_OSFILE**  
Exit code that means some system file did not exist, could not be opened, or had some other kind of error.  
Availability: Unix. New in version 2.3.
- os.**EX\_CANTCREAT**  
Exit code that means a user specified output file could not be created.  
Availability: Unix. New in version 2.3.
- os.**EX\_IOERR**  
Exit code that means that an error occurred while doing I/O on some file.  
Availability: Unix. New in version 2.3.
- os.**EX\_TEMPFAIL**  
Exit code that means a temporary failure occurred. This indicates something that may not really be an error, such as a network connection that couldn't be made during a retryable operation.  
Availability: Unix. New in version 2.3.
- os.**EX\_PROTOCOL**  
Exit code that means that a protocol exchange was illegal, invalid, or not understood.  
Availability: Unix. New in version 2.3.
- os.**EX\_NOPERM**  
Exit code that means that there were insufficient permissions to perform the operation (but not intended for file system problems).  
Availability: Unix. New in version 2.3.

### os.EX\_CONFIG

Exit code that means that some kind of configuration error occurred.

Availability: Unix. New in version 2.3.

### os.EX\_NOTFOUND

Exit code that means something like “an entry was not found”.

Availability: Unix. New in version 2.3.

### os.fork()

Fork a child process. Return 0 in the child and the child’s process id in the parent. If an error occurs `OSError` is raised.

Note that some platforms including FreeBSD <= 6.3, Cygwin and OS/2 EMX have known issues when using `fork()` from a thread.

Availability: Unix.

### os.forkpty()

Fork a child process, using a new pseudo-terminal as the child’s controlling terminal. Return a pair of (`pid`, `fd`), where `pid` is 0 in the child, the new child’s process id in the parent, and `fd` is the file descriptor of the master end of the pseudo-terminal. For a more portable approach, use the `pty` module. If an error occurs `OSError` is raised.

Availability: some flavors of Unix.

### os.kill(pid, sig)

Send signal `sig` to the process `pid`. Constants for the specific signals available on the host platform are defined in the `signal` module.

Windows: The `signal.CTRL_C_EVENT` and `signal.CTRL_BREAK_EVENT` signals are special signals which can only be sent to console processes which share a common console window, e.g., some subprocesses. Any other value for `sig` will cause the process to be unconditionally killed by the `TerminateProcess` API, and the exit code will be set to `sig`. The Windows version of `kill()` additionally takes process handles to be killed.  
New in version 2.7: Windows support

### os.killpg(pgid, sig)

Send the signal `sig` to the process group `pgid`.

Availability: Unix. New in version 2.3.

### os.nice(increment)

Add `increment` to the process’s “niceness”. Return the new niceness.

Availability: Unix.

### os.plock(op)

Lock program segments into memory. The value of `op` (defined in `<sys/lock.h>`) determines which segments are locked.

Availability: Unix.

### os.popen(...)

### os.popen2(...)

### os.popen3(...)

### os.popen4(...)

Run child processes, returning opened pipes for communications. These functions are described in section [File Object Creation](#).

### os.spawnl(mode, path, ...)

### os.spawnle(mode, path, ..., env)

### os.spawnlp(mode, file, ...)

- os.**spawnlpe** (*mode*, *file*, ..., *env*)
- os.**spawnv** (*mode*, *path*, *args*)
- os.**spawnve** (*mode*, *path*, *args*, *env*)
- os.**spawnvp** (*mode*, *file*, *args*)
- os.**spawnvpe** (*mode*, *file*, *args*, *env*)

Execute the program *path* in a new process.

(Note that the `subprocess` module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using these functions. Check especially the *Replacing Older Functions with the subprocess Module* section.)

If *mode* is `P_NOWAIT`, this function returns the process id of the new process; if *mode* is `P_WAIT`, returns the process's exit code if it exits normally, or `-signal`, where *signal* is the signal that killed the process. On Windows, the process id will actually be the process handle, so can be used with the `waitpid()` function.

The “l” and “v” variants of the `spawn*()` functions differ in how command-line arguments are passed. The “l” variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the `spawnl*()` functions. The “v” variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the *args* parameter. In either case, the arguments to the child process must start with the name of the command being run.

The variants which include a second “p” near the end (`spawnlp()`, `spawnlpe()`, `spawnvp()`, and `spawnvpe()`) will use the

`PATH` environment variable to locate the program *file*. When the environment is being replaced (using one of the `spawn*e()` variants, discussed in the next paragraph), the new environment is used as the source of the `PATH` variable. The other variants, `spawnl()`, `spawnle()`, `spawnv()`, and `spawnve()`, will not use the `PATH` variable to locate the executable; *path* must contain an appropriate absolute or relative path.

For `spawnle()`, `spawnlpe()`, `spawnve()`, and `spawnvpe()` (note that these all end in “e”), the *env* parameter must be a mapping which is used to define the environment variables for the new process (they are used instead of the current process' environment); the functions `spawnl()`, `spawnlp()`, `spawnv()`, and `spawnvp()` all cause the new process to inherit the environment of the current process. Note that keys and values in the *env* dictionary must be strings; invalid keys or values will cause the function to fail, with a return value of 127.

As an example, the following calls to `spawnlp()` and `spawnvpe()` are equivalent:

```
import os
os.spawnlp(os.P_WAIT, 'cp', 'cp', 'index.html', '/dev/null')

L = ['cp', 'index.html', '/dev/null']
os.spawnvpe(os.P_WAIT, 'cp', L, os.environ)
```

Availability: Unix, Windows. `spawnlp()`, `spawnlpe()`, `spawnvp()` and `spawnvpe()` are not available on Windows. `spawnle()` and `spawnve()` are not thread-safe on Windows; we advise you to use the `subprocess` module instead. New in version 1.6.

- os.**P\_NOWAIT**
- os.**P\_NOWAITO**

Possible values for the *mode* parameter to the `spawn*()` family of functions. If either of these values is given, the `spawn*()` functions will return as soon as the new process has been created, with the process id as the return value.

Availability: Unix, Windows. New in version 1.6.

### os.P\_WAIT

Possible value for the *mode* parameter to the `spawn*()` family of functions. If this is given as *mode*, the `spawn*()` functions will not return until the new process has run to completion and will return the exit code of the process the run is successful, or `-signal` if a signal kills the process.

Availability: Unix, Windows. New in version 1.6.

### os.P\_DETACH

### os.P\_OVERLAY

Possible values for the *mode* parameter to the `spawn*()` family of functions. These are less portable than those listed above. `P_DETACH` is similar to `P_NOWAIT`, but the new process is detached from the console of the calling process. If `P_OVERLAY` is used, the current process will be replaced; the `spawn*()` function will not return.

Availability: Windows. New in version 1.6.

### os.startfile(*path*[, *operation*])

Start a file with its associated application.

When *operation* is not specified or `'open'`, this acts like double-clicking the file in Windows Explorer, or giving the file name as an argument to the `start` command from the interactive command shell: the file is opened with whatever application (if any) its extension is associated.

When another *operation* is given, it must be a “command verb” that specifies what should be done with the file. Common verbs documented by Microsoft are `'print'` and `'edit'` (to be used on files) as well as `'explore'` and `'find'` (to be used on directories).

`startfile()` returns as soon as the associated application is launched. There is no option to wait for the application to close, and no way to retrieve the application’s exit status. The *path* parameter is relative to the current directory. If you want to use an absolute path, make sure the first character is not a slash (`'/'`); the underlying Win32 `ShellExecute()` function doesn’t work if it is. Use the `os.path.normpath()` function to ensure that the path is properly encoded for Win32.

Availability: Windows. New in version 2.0. New in version 2.5: The *operation* parameter.

### os.system(*command*)

Execute the command (a string) in a subshell. This is implemented by calling the Standard C function `system()`, and has the same limitations. Changes to `sys.stdin`, etc. are not reflected in the environment of the executed command.

On Unix, the return value is the exit status of the process encoded in the format specified for `wait()`. Note that POSIX does not specify the meaning of the return value of the C `system()` function, so the return value of the Python function is system-dependent.

On Windows, the return value is that returned by the system shell after running *command*, given by the Windows environment variable `COMSPEC`: on **command.com** systems (Windows 95, 98 and ME) this is always 0; on **cmd.exe** systems (Windows NT, 2000 and XP) this is the exit status of the command run; on systems using a non-native shell, consult your shell documentation.

The `subprocess` module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using this function. See the *Replacing Older Functions with the subprocess Module* section in the `subprocess` documentation for some helpful recipes.

Availability: Unix, Windows.

### os.times()

Return a 5-tuple of floating point numbers indicating accumulated (processor or other) times, in seconds. The items are: user time, system time, children’s user time, children’s system time, and elapsed real time since a fixed point in the past, in that order. See the Unix manual page `times(2)` or the corresponding Windows Platform API documentation. On Windows, only the first two items are filled, the others are zero.

Availability: Unix, Windows

**os.wait()**

Wait for completion of a child process, and return a tuple containing its pid and exit status indication: a 16-bit number, whose low byte is the signal number that killed the process, and whose high byte is the exit status (if the signal number is zero); the high bit of the low byte is set if a core file was produced.

Availability: Unix.

**os.waitpid(pid, options)**

The details of this function differ on Unix and Windows.

On Unix: Wait for completion of a child process given by process id *pid*, and return a tuple containing its process id and exit status indication (encoded as for `wait()`). The semantics of the call are affected by the value of the integer *options*, which should be 0 for normal operation.

If *pid* is greater than 0, `waitpid()` requests status information for that specific process. If *pid* is 0, the request is for the status of any child in the process group of the current process. If *pid* is -1, the request pertains to any child of the current process. If *pid* is less than -1, status is requested for any process in the process group `-pid` (the absolute value of *pid*).

An `OSError` is raised with the value of `errno` when the syscall returns -1.

On Windows: Wait for completion of a process given by process handle *pid*, and return a tuple containing *pid*, and its exit status shifted left by 8 bits (shifting makes cross-platform use of the function easier). A *pid* less than or equal to 0 has no special meaning on Windows, and raises an exception. The value of integer *options* has no effect. *pid* can refer to any process whose id is known, not necessarily a child process. The `spawn()` functions called with `P_NOWAIT` return suitable process handles.

**os.wait3([options])**

Similar to `waitpid()`, except no process id argument is given and a 3-element tuple containing the child's process id, exit status indication, and resource usage information is returned. Refer to `resource.getrusage()` for details on resource usage information. The option argument is the same as that provided to `waitpid()` and `wait4()`.

Availability: Unix. New in version 2.5.

**os.wait4(pid, options)**

Similar to `waitpid()`, except a 3-element tuple, containing the child's process id, exit status indication, and resource usage information is returned. Refer to `resource.getrusage()` for details on resource usage information. The arguments to `wait4()` are the same as those provided to `waitpid()`.

Availability: Unix. New in version 2.5.

**os.WNOHANG**

The option for `waitpid()` to return immediately if no child process status is available immediately. The function returns (0, 0) in this case.

Availability: Unix.

**os.WCONTINUED**

This option causes child processes to be reported if they have been continued from a job control stop since their status was last reported.

Availability: Some Unix systems. New in version 2.3.

**os.WUNTRACED**

This option causes child processes to be reported if they have been stopped but their current state has not been reported since they were stopped.

Availability: Unix. New in version 2.3.

The following functions take a process status code as returned by `system()`, `wait()`, or `waitpid()` as a parameter. They may be used to determine the disposition of a process.

- **`os.WCOREDUMP`** (*status*)  
Return `True` if a core dump was generated for the process, otherwise return `False`.  
Availability: Unix. New in version 2.3.
- **`os.WIFCONTINUED`** (*status*)  
Return `True` if the process has been continued from a job control stop, otherwise return `False`.  
Availability: Unix. New in version 2.3.
- **`os.WIFSTOPPED`** (*status*)  
Return `True` if the process has been stopped, otherwise return `False`.  
Availability: Unix.
- **`os.WIFSIGNALED`** (*status*)  
Return `True` if the process exited due to a signal, otherwise return `False`.  
Availability: Unix.
- **`os.WIFEXITED`** (*status*)  
Return `True` if the process exited using the `exit(2)` system call, otherwise return `False`.  
Availability: Unix.
- **`os.WEXITSTATUS`** (*status*)  
If `WIFEXITED(status)` is true, return the integer parameter to the `exit(2)` system call. Otherwise, the return value is meaningless.  
Availability: Unix.
- **`os.WSTOPSIG`** (*status*)  
Return the signal which caused the process to stop.  
Availability: Unix.
- **`os.WTERMSIG`** (*status*)  
Return the signal which caused the process to exit.  
Availability: Unix.

### 15.1.6 Miscellaneous System Information

- **`os.confstr`** (*name*)  
Return string-valued system configuration values. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given as the keys of the `confstr_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.  
  
If the configuration value specified by *name* isn't defined, `None` is returned.  
  
If *name* is a string and is not known, `ValueError` is raised. If a specific value for *name* is not supported by the host system, even if it is included in `confstr_names`, an `OSError` is raised with `errno.EINVAL` for the error number.  
  
Availability: Unix

**os.confstr\_names**

Dictionary mapping names accepted by `confstr()` to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

**os.getloadavg()**

Return the number of processes in the system run queue averaged over the last 1, 5, and 15 minutes or raises `OSError` if the load average was unobtainable.

Availability: Unix. New in version 2.3.

**os.sysconf(name)**

Return integer-valued system configuration values. If the configuration value specified by *name* isn't defined, `-1` is returned. The comments regarding the *name* parameter for `confstr()` apply here as well; the dictionary that provides information on the known names is given by `sysconf_names`.

Availability: Unix.

**os.sysconf\_names**

Dictionary mapping names accepted by `sysconf()` to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

The following data values are used to support path manipulation operations. These are defined for all platforms.

Higher-level operations on pathnames are defined in the `os.path` module.

**os.curdir**

The constant string used by the operating system to refer to the current directory. This is `'.'` for Windows and POSIX. Also available via `os.path`.

**os.pardir**

The constant string used by the operating system to refer to the parent directory. This is `'..'` for Windows and POSIX. Also available via `os.path`.

**os.sep**

The character used by the operating system to separate pathname components. This is `'/'` for POSIX and `'\\'` for Windows. Note that knowing this is not sufficient to be able to parse or concatenate pathnames — use `os.path.split()` and `os.path.join()` — but it is occasionally useful. Also available via `os.path`.

**os.altsep**

An alternative character used by the operating system to separate pathname components, or `None` if only one separator character exists. This is set to `'/'` on Windows systems where `sep` is a backslash. Also available via `os.path`.

**os.extsep**

The character which separates the base filename from the extension; for example, the `'.'` in `os.py`. Also available via `os.path`. New in version 2.2.

**os.pathsep**

The character conventionally used by the operating system to separate search path components (as in `PATH`), such as `':'` for POSIX or  `';'`  for Windows. Also available via `os.path`.

**os.defpath**

The default search path used by `exec*py*()` and `spawn*py*()` if the environment doesn't have a `'PATH'` key. Also available via `os.path`.

**os.linesep**

The string used to separate (or, rather, terminate) lines on the current platform. This may be a single character,

such as `'\n'` for POSIX, or multiple characters, for example, `'\r\n'` for Windows. Do not use `os.linesep` as a line terminator when writing files opened in text mode (the default); use a single `'\n'` instead, on all platforms.

### `os.devnull`

The file path of the null device. For example: `'/dev/null'` for POSIX, `'nul'` for Windows. Also available via `os.path`. New in version 2.4.

## 15.1.7 Miscellaneous Functions

### `os.urandom(n)`

Return a string of  $n$  random bytes suitable for cryptographic use.

This function returns random bytes from an OS-specific randomness source. The returned data should be unpredictable enough for cryptographic applications, though its exact quality depends on the OS implementation. On a UNIX-like system this will query `/dev/urandom`, and on Windows it will use `CryptGenRandom`. If a randomness source is not found, `NotImplementedError` will be raised. New in version 2.4.

## 15.2 `io` — Core tools for working with streams

New in version 2.6. The `io` module provides the Python interfaces to stream handling. Under Python 2.x, this is proposed as an alternative to the built-in `file` object, but in Python 3.x it is the default interface to access files and streams.

---

**Note:** Since this module has been designed primarily for Python 3.x, you have to be aware that all uses of “bytes” in this document refer to the `str` type (of which `bytes` is an alias), and all uses of “text” refer to the `unicode` type. Furthermore, those two types are not interchangeable in the `io` APIs.

---

At the top of the I/O hierarchy is the abstract base class `IOBase`. It defines the basic interface to a stream. Note, however, that there is no separation between reading and writing to streams; implementations are allowed to raise an `IOError` if they do not support a given operation.

Extending `IOBase` is `RawIOBase` which deals simply with the reading and writing of raw bytes to a stream. `FileIO` subclasses `RawIOBase` to provide an interface to files in the machine’s file system.

`BufferedIOBase` deals with buffering on a raw byte stream (`RawIOBase`). Its subclasses, `BufferedWriter`, `BufferedReader`, and `BufferedRWPair` buffer streams that are readable, writable, and both readable and writable. `BufferedRandom` provides a buffered interface to random access streams. `BytesIO` is a simple stream of in-memory bytes.

Another `IOBase` subclass, `TextIOBase`, deals with streams whose bytes represent text, and handles encoding and decoding from and to `unicode` strings. `TextIOWrapper`, which extends it, is a buffered text interface to a buffered raw stream (`BufferedIOBase`). Finally, `StringIO` is an in-memory stream for unicode text.

Argument names are not part of the specification, and only the arguments of `open()` are intended to be used as keyword arguments.

### 15.2.1 Module Interface

#### `io.DEFAULT_BUFFER_SIZE`

An int containing the default buffer size used by the module’s buffered I/O classes. `open()` uses the file’s `blksize` (as obtained by `os.stat()`) if possible.

`io.open` (*file*, *mode*='r', *buffering*=-1, *encoding*=None, *errors*=None, *newline*=None, *closefd*=True)

Open *file* and return a corresponding stream. If the file cannot be opened, an `IOError` is raised.

*file* is either a string giving the pathname (absolute or relative to the current working directory) of the file to be opened or an integer file descriptor of the file to be wrapped. (If a file descriptor is given, it is closed when the returned I/O object is closed, unless *closefd* is set to `False`.)

*mode* is an optional string that specifies the mode in which the file is opened. It defaults to 'r' which means open for reading in text mode. Other common values are 'w' for writing (truncating the file if it already exists), and 'a' for appending (which on *some* Unix systems, means that *all* writes append to the end of the file regardless of the current seek position). In text mode, if *encoding* is not specified the encoding used is platform dependent. (For reading and writing raw bytes use binary mode and leave *encoding* unspecified.) The available modes are:

Character	Meaning
'r'	open for reading (default)
'w'	open for writing, truncating the file first
'a'	open for writing, appending to the end of the file if it exists
'b'	binary mode
't'	text mode (default)
'+'	open a disk file for updating (reading and writing)
'U'	universal newlines mode (for backwards compatibility; should not be used in new code)

The default mode is 'rt' (open for reading text). For binary random access, the mode 'w+b' opens and truncates the file to 0 bytes, while 'r+b' opens the file without truncation.

Python distinguishes between files opened in binary and text modes, even when the underlying operating system doesn't. Files opened in binary mode (including 'b' in the *mode* argument) return contents as `bytes` objects without any decoding. In text mode (the default, or when 't' is included in the *mode* argument), the contents of the file are returned as `unicode` strings, the bytes having been first decoded using a platform-dependent encoding or using the specified *encoding* if given.

*buffering* is an optional integer used to set the buffering policy. Pass 0 to switch buffering off (only allowed in binary mode), 1 to select line buffering (only usable in text mode), and an integer > 1 to indicate the size of a fixed-size chunk buffer. When no *buffering* argument is given, the default buffering policy works as follows:

- Binary files are buffered in fixed-size chunks; the size of the buffer is chosen using a heuristic trying to determine the underlying device's "block size" and falling back on `DEFAULT_BUFFER_SIZE`. On many systems, the buffer will typically be 4096 or 8192 bytes long.
- "Interactive" text files (files for which `isatty()` returns `True`) use line buffering. Other text files use the policy described above for binary files.

*encoding* is the name of the encoding used to decode or encode the file. This should only be used in text mode. The default encoding is platform dependent (whatever `locale.getpreferredencoding()` returns), but any encoding supported by Python can be used. See the `codecs` module for the list of supported encodings.

*errors* is an optional string that specifies how encoding and decoding errors are to be handled—this cannot be used in binary mode. Pass 'strict' to raise a `ValueError` exception if there is an encoding error (the default of `None` has the same effect), or pass 'ignore' to ignore errors. (Note that ignoring encoding errors can lead to data loss.) 'replace' causes a replacement marker (such as '?') to be inserted where there is malformed data. When writing, 'xmlcharrefreplace' (replace with the appropriate XML character reference) or 'backslashreplace' (replace with backslashed escape sequences) can be used. Any other error handling name that has been registered with `codecs.register_error()` is also valid.

*newline* controls how *universal newlines* works (it only applies to text mode). It can be `None`, '', '\n', '\r', and '\r\n'. It works as follows:

- On input, if *newline* is `None`, universal newlines mode is enabled. Lines in the input can end in '\n', '\r', or '\r\n', and these are translated into '\n' before being returned to the caller. If it is '',

universal newlines mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are only terminated by the given string, and the line ending is returned to the caller untranslated.

- On output, if *newline* is `None`, any `'\n'` characters written are translated to the system default line separator, `os.linesep`. If *newline* is `"`, no translation takes place. If *newline* is any of the other legal values, any `'\n'` characters written are translated to the given string.

If *closefd* is `False` and a file descriptor rather than a filename was given, the underlying file descriptor will be kept open when the file is closed. If a filename is given *closefd* has no effect and must be `True` (the default).

The type of file object returned by the `open()` function depends on the mode. When `open()` is used to open a file in a text mode (`'w'`, `'r'`, `'wt'`, `'rt'`, etc.), it returns a subclass of `TextIOBase` (specifically `TextIOWrapper`). When used to open a file in a binary mode with buffering, the returned class is a subclass of `BufferedIOBase`. The exact class varies: in read binary mode, it returns a `BufferedReader`; in write binary and append binary modes, it returns a `BufferedWriter`, and in read/write mode, it returns a `BufferedRandom`. When buffering is disabled, the raw stream, a subclass of `RawIOBase`, `FileIO`, is returned.

It is also possible to use an `unicode` or `bytes` string as a file for both reading and writing. For `unicode` strings `StringIO` can be used like a file opened in text mode, and for `bytes` a `BytesIO` can be used like a file opened in a binary mode.

### exception `io.BlockingIOError`

Error raised when blocking would occur on a non-blocking stream. It inherits `IOError`.

In addition to those of `IOError`, `BlockingIOError` has one attribute:

#### `characters_written`

An integer containing the number of characters written to the stream before it blocked.

### exception `io.UnsupportedOperation`

An exception inheriting `IOError` and `ValueError` that is raised when an unsupported operation is called on a stream.

## 15.2.2 I/O Base Classes

### class `io.IOBase`

The abstract base class for all I/O classes, acting on streams of bytes. There is no public constructor.

This class provides empty abstract implementations for many methods that derived classes can override selectively; the default implementations represent a file that cannot be read, written or seeked.

Even though `IOBase` does not declare `read()`, `readinto()`, or `write()` because their signatures will vary, implementations and clients should consider those methods part of the interface. Also, implementations may raise a `IOError` when operations they do not support are called.

The basic type used for binary data read from or written to a file is `bytes` (also known as `str`). `bytearrays` are accepted too, and in some cases (such as `readinto()`) required. Text I/O classes work with `unicode` data.

Note that calling any method (even inquiries) on a closed stream is undefined. Implementations may raise `IOError` in this case.

`IOBase` (and its subclasses) support the iterator protocol, meaning that an `IOBase` object can be iterated over yielding the lines in a stream. Lines are defined slightly differently depending on whether the stream is a binary stream (yielding `bytes`), or a text stream (yielding `unicode` strings). See `readline()` below.

`IOBase` is also a context manager and therefore supports the `with` statement. In this example, *file* is closed after the `with` statement's suite is finished—even if an exception occurs:

```
with io.open('spam.txt', 'w') as file:
    file.write(u'Spam and eggs!')
```

`IOBase` provides these data attributes and methods:

**close()**

Flush and close this stream. This method has no effect if the file is already closed. Once the file is closed, any operation on the file (e.g. reading or writing) will raise a `ValueError`.

As a convenience, it is allowed to call this method more than once; only the first call, however, will have an effect.

**closed**

True if the stream is closed.

**fileno()**

Return the underlying file descriptor (an integer) of the stream if it exists. An `IOError` is raised if the `IO` object does not use a file descriptor.

**flush()**

Flush the write buffers of the stream if applicable. This does nothing for read-only and non-blocking streams.

**isatty()**

Return `True` if the stream is interactive (i.e., connected to a terminal/tty device).

**readable()**

Return `True` if the stream can be read from. If `False`, `read()` will raise `IOError`.

**readline(*limit=-1*)**

Read and return one line from the stream. If *limit* is specified, at most *limit* bytes will be read.

The line terminator is always `b'\n'` for binary files; for text files, the *newlines* argument to `open()` can be used to select the line terminator(s) recognized.

**readlines(*hint=-1*)**

Read and return a list of lines from the stream. *hint* can be specified to control the number of lines read: no more lines will be read if the total size (in bytes/characters) of all lines so far exceeds *hint*.

**seek(*offset, whence=SEEK\_SET*)**

Change the stream position to the given byte *offset*. *offset* is interpreted relative to the position indicated by *whence*. Values for *whence* are:

- `SEEK_SET` or 0 – start of the stream (the default); *offset* should be zero or positive
- `SEEK_CUR` or 1 – current stream position; *offset* may be negative
- `SEEK_END` or 2 – end of the stream; *offset* is usually negative

Return the new absolute position. New in version 2.7: The `SEEK_*` constants

**seekable()**

Return `True` if the stream supports random access. If `False`, `seek()`, `tell()` and `truncate()` will raise `IOError`.

**tell()**

Return the current stream position.

**truncate(*size=None*)**

Resize the stream to the given *size* in bytes (or the current position if *size* is not specified). The current stream position isn't changed. This resizing can extend or reduce the current file size. In case of extension, the contents of the new file area depend on the platform (on most systems, additional bytes are zero-filled, on Windows they're undetermined). The new file size is returned.

**writable()**

Return True if the stream supports writing. If False, `write()` and `truncate()` will raise `IOError`.

**writelines(*lines*)**

Write a list of lines to the stream. Line separators are not added, so it is usual for each of the lines provided to have a line separator at the end.

**class `io.RawIOBase`**

Base class for raw binary I/O. It inherits `IOBase`. There is no public constructor.

Raw binary I/O typically provides low-level access to an underlying OS device or API, and does not try to encapsulate it in high-level primitives (this is left to Buffered I/O and Text I/O, described later in this page).

In addition to the attributes and methods from `IOBase`, `RawIOBase` provides the following methods:

**read(*n=-1*)**

Read up to *n* bytes from the object and return them. As a convenience, if *n* is unspecified or -1, `readall()` is called. Otherwise, only one system call is ever made. Fewer than *n* bytes may be returned if the operating system call returns fewer than *n* bytes.

If 0 bytes are returned, and *n* was not 0, this indicates end of file. If the object is in non-blocking mode and no bytes are available, `None` is returned.

**readall()**

Read and return all the bytes from the stream until EOF, using multiple calls to the stream if necessary.

**readinto(*b*)**

Read up to `len(b)` bytes into bytearray *b* and return the number of bytes read. If the object is in non-blocking mode and no bytes are available, `None` is returned.

**write(*b*)**

Write the given bytes or bytearray object, *b*, to the underlying raw stream and return the number of bytes written. This can be less than `len(b)`, depending on specifics of the underlying raw stream, and especially if it is in non-blocking mode. `None` is returned if the raw stream is set not to block and no single byte could be readily written to it.

**class `io.BufferedIOBase`**

Base class for binary streams that support some kind of buffering. It inherits `IOBase`. There is no public constructor.

The main difference with `RawIOBase` is that methods `read()`, `readinto()` and `write()` will try (respectively) to read as much input as requested or to consume all given output, at the expense of making perhaps more than one system call.

In addition, those methods can raise `BlockingIOError` if the underlying raw stream is in non-blocking mode and cannot take or give enough data; unlike their `RawIOBase` counterparts, they will never return `None`.

Besides, the `read()` method does not have a default implementation that defers to `readinto()`.

A typical `BufferedIOBase` implementation should not inherit from a `RawIOBase` implementation, but wrap one, like `BufferedWriter` and `BufferedReader` do.

`BufferedIOBase` provides or overrides these methods and attribute in addition to those from `IOBase`:

**raw**

The underlying raw stream (a `RawIOBase` instance) that `BufferedIOBase` deals with. This is not part of the `BufferedIOBase` API and may not exist on some implementations.

**detach()**

Separate the underlying raw stream from the buffer and return it.

After the raw stream has been detached, the buffer is in an unusable state.

Some buffers, like `BytesIO`, do not have the concept of a single raw stream to return from this method. They raise `UnsupportedOperation`. New in version 2.7.

**read** (*n=-1*)

Read and return up to *n* bytes. If the argument is omitted, `None`, or negative, data is read and returned until EOF is reached. An empty bytes object is returned if the stream is already at EOF.

If the argument is positive, and the underlying raw stream is not interactive, multiple raw reads may be issued to satisfy the byte count (unless EOF is reached first). But for interactive raw streams, at most one raw read will be issued, and a short result does not imply that EOF is imminent.

A `BlockingIOError` is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

**read1** (*n=-1*)

Read and return up to *n* bytes, with at most one call to the underlying raw stream's `read()` method. This can be useful if you are implementing your own buffering on top of a `BufferedIOBase` object.

**readinto** (*b*)

Read up to `len(b)` bytes into bytearray *b* and return the number of bytes read.

Like `read()`, multiple reads may be issued to the underlying raw stream, unless the latter is 'interactive'.

A `BlockingIOError` is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

**write** (*b*)

Write the given bytes or bytearray object, *b* and return the number of bytes written (never less than `len(b)`, since if the write fails an `IOError` will be raised). Depending on the actual implementation, these bytes may be readily written to the underlying stream, or held in a buffer for performance and latency reasons.

When in non-blocking mode, a `BlockingIOError` is raised if the data needed to be written to the raw stream but it couldn't accept all the data without blocking.

### 15.2.3 Raw File I/O

**class** `io.FileIO` (*name, mode='r', closefd=True*)

`FileIO` represents an OS-level file containing bytes data. It implements the `RawIOBase` interface (and therefore the `IOBase` interface, too).

The *name* can be one of two things:

- a string representing the path to the file which will be opened;
- an integer representing the number of an existing OS-level file descriptor to which the resulting `FileIO` object will give access.

The *mode* can be `'r'`, `'w'` or `'a'` for reading (default), writing, or appending. The file will be created if it doesn't exist when opened for writing or appending; it will be truncated when opened for writing. Add a `'+'` to the mode to allow simultaneous reading and writing.

The `read()` (when called with a positive argument), `readinto()` and `write()` methods on this class will only make one system call.

In addition to the attributes and methods from `IOBase` and `RawIOBase`, `FileIO` provides the following data attributes and methods:

**mode**

The mode as given in the constructor.

**name**

The file name. This is the file descriptor of the file when no name is given in the constructor.

## 15.2.4 Buffered Streams

Buffered I/O streams provide a higher-level interface to an I/O device than raw I/O does.

**class** `io.BytesIO` (`[initial_bytes]`)

A stream implementation using an in-memory bytes buffer. It inherits `BufferedIOBase`.

The argument `initial_bytes` is an optional initial bytes.

`BytesIO` provides or overrides these methods in addition to those from `BufferedIOBase` and `IOBase`:

**getvalue** ()

Return bytes containing the entire contents of the buffer.

**read1** ()

In `BytesIO`, this is the same as `read()`.

**class** `io.BufferedReader` (`raw, buffer_size=DEFAULT_BUFFER_SIZE`)

A buffer providing higher-level access to a readable, sequential `RawIOBase` object. It inherits `BufferedIOBase`. When reading data from this object, a larger amount of data may be requested from the underlying raw stream, and kept in an internal buffer. The buffered data can then be returned directly on subsequent reads.

The constructor creates a `BufferedReader` for the given readable `raw` stream and `buffer_size`. If `buffer_size` is omitted, `DEFAULT_BUFFER_SIZE` is used.

`BufferedReader` provides or overrides these methods in addition to those from `BufferedIOBase` and `IOBase`:

**peek** (`[n]`)

Return bytes from the stream without advancing the position. At most one single read on the raw stream is done to satisfy the call. The number of bytes returned may be less or more than requested.

**read** (`[n]`)

Read and return `n` bytes, or if `n` is not given or negative, until EOF or if the read call would block in non-blocking mode.

**read1** (`n`)

Read and return up to `n` bytes with only one call on the raw stream. If at least one byte is buffered, only buffered bytes are returned. Otherwise, one raw stream read call is made.

**class** `io.BufferedWriter` (`raw, buffer_size=DEFAULT_BUFFER_SIZE`)

A buffer providing higher-level access to a writable, sequential `RawIOBase` object. It inherits `BufferedIOBase`. When writing to this object, data is normally held into an internal buffer. The buffer will be written out to the underlying `RawIOBase` object under various conditions, including:

- when the buffer gets too small for all pending data;
- when `flush()` is called;
- when a `seek()` is requested (for `BufferedRandom` objects);
- when the `BufferedWriter` object is closed or destroyed.

The constructor creates a `BufferedWriter` for the given writable `raw` stream. If the `buffer_size` is not given, it defaults to `DEFAULT_BUFFER_SIZE`.

A third argument, `max_buffer_size`, is supported, but unused and deprecated.

`BufferedWriter` provides or overrides these methods in addition to those from `BufferedIOBase` and `IOBase`:

**flush()**

Force bytes held in the buffer into the raw stream. A `BlockingIOError` should be raised if the raw stream blocks.

**write(b)**

Write the bytes or bytearray object, *b* and return the number of bytes written. When in non-blocking mode, a `BlockingIOError` is raised if the buffer needs to be written out but the raw stream blocks.

**class** `io.BufferedReader`(*raw*, *buffer\_size*=`DEFAULT_BUFFER_SIZE`)

A buffered interface to random access streams. It inherits `BufferedReader` and `BufferedWriter`, and further supports `seek()` and `tell()` functionality.

The constructor creates a reader and writer for a seekable raw stream, given in the first argument. If the *buffer\_size* is omitted it defaults to `DEFAULT_BUFFER_SIZE`.

A third argument, *max\_buffer\_size*, is supported, but unused and deprecated.

`BufferedReader` is capable of anything `BufferedReader` or `BufferedWriter` can do.

**class** `io.BufferedRWPair`(*reader*, *writer*, *buffer\_size*=`DEFAULT_BUFFER_SIZE`)

A buffered I/O object combining two unidirectional `RawIOBase` objects – one readable, the other writeable – into a single bidirectional endpoint. It inherits `BufferedIOBase`.

*reader* and *writer* are `RawIOBase` objects that are readable and writeable respectively. If the *buffer\_size* is omitted it defaults to `DEFAULT_BUFFER_SIZE`.

A fourth argument, *max\_buffer\_size*, is supported, but unused and deprecated.

`BufferedRWPair` implements all of `BufferedIOBase`'s methods except for `detach()`, which raises `UnsupportedOperation`.

**Warning:** `BufferedRWPair` does not attempt to synchronize accesses to its underlying raw streams. You should not pass it the same object as reader and writer; use `BufferedReader` instead.

## 15.2.5 Text I/O

**class** `io.TextIOBase`

Base class for text streams. This class provides a unicode character and line based interface to stream I/O. There is no `readinto()` method because Python's unicode strings are immutable. It inherits `IOBase`. There is no public constructor.

`TextIOBase` provides or overrides these data attributes and methods in addition to those from `IOBase`:

**encoding**

The name of the encoding used to decode the stream's bytes into strings, and to encode strings into bytes.

**errors**

The error setting of the decoder or encoder.

**newlines**

A string, a tuple of strings, or `None`, indicating the newlines translated so far. Depending on the implementation and the initial constructor flags, this may not be available.

**buffer**

The underlying binary buffer (a `BufferedIOBase` instance) that `TextIOBase` deals with. This is not part of the `TextIOBase` API and may not exist on some implementations.

**detach()**

Separate the underlying binary buffer from the `TextIOBase` and return it.

After the underlying buffer has been detached, the `TextIOBase` is in an unusable state.

Some `TextIOBase` implementations, like `StringIO`, may not have the concept of an underlying buffer and calling this method will raise `UnsupportedOperation`. New in version 2.7.

**read(*n*)**

Read and return at most *n* characters from the stream as a single `unicode`. If *n* is negative or `None`, reads until EOF.

**readline(*limit=-1*)**

Read until newline or EOF and return a single `unicode`. If the stream is already at EOF, an empty string is returned.

If *limit* is specified, at most *limit* characters will be read.

**seek(*offset, whence=SEEK\_SET*)**

Change the stream position to the given *offset*. Behaviour depends on the *whence* parameter:

- `SEEK_SET` or 0: seek from the start of the stream (the default); *offset* must either be a number returned by `TextIOBase.tell()`, or zero. Any other *offset* value produces undefined behaviour.
- `SEEK_CUR` or 1: “seek” to the current position; *offset* must be zero, which is a no-operation (all other values are unsupported).
- `SEEK_END` or 2: seek to the end of the stream; *offset* must be zero (all other values are unsupported).

Return the new absolute position as an opaque number. New in version 2.7: The `SEEK_*` constants.

**tell()**

Return the current stream position as an opaque number. The number does not usually represent a number of bytes in the underlying binary storage.

**write(*s*)**

Write the `unicode` string *s* to the stream and return the number of characters written.

**class io.TextIOWrapper(*buffer, encoding=None, errors=None, newline=None, line\_buffering=False*)**

A buffered text stream over a `BufferedIOBase` binary stream. It inherits `TextIOBase`.

*encoding* gives the name of the encoding that the stream will be decoded or encoded with. It defaults to `locale.getpreferredencoding()`.

*errors* is an optional string that specifies how encoding and decoding errors are to be handled. Pass `'strict'` to raise a `ValueError` exception if there is an encoding error (the default of `None` has the same effect), or pass `'ignore'` to ignore errors. (Note that ignoring encoding errors can lead to data loss.) `'replace'` causes a replacement marker (such as `'?'`) to be inserted where there is malformed data. When writing, `'xmlcharrefreplace'` (replace with the appropriate XML character reference) or `'backslashreplace'` (replace with backslashed escape sequences) can be used. Any other error handling name that has been registered with `codecs.register_error()` is also valid.

*newline* controls how line endings are handled. It can be `None`, `"`, `'\n'`, `'\r'`, and `'\r\n'`. It works as follows:

- On input, if *newline* is `None`, *universal newlines* mode is enabled. Lines in the input can end in `'\n'`, `'\r'`, or `'\r\n'`, and these are translated into `'\n'` before being returned to the caller. If it is `"`, universal newlines mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are only terminated by the given string, and the line ending is returned to the caller untranslated.

- On output, if `newline` is `None`, any `'\n'` characters written are translated to the system default line separator, `os.linesep`. If `newline` is `"`, no translation takes place. If `newline` is any of the other legal values, any `'\n'` characters written are translated to the given string.

If `line_buffering` is `True`, `flush()` is implied when a call to `write` contains a newline character.

`TextIOWrapper` provides one attribute in addition to those of `TextIOBase` and its parents:

#### **line\_buffering**

Whether line buffering is enabled.

**class** `io.StringIO` (*initial\_value=u', newline=None*)

An in-memory stream for unicode text. It inherits `TextIOWrapper`.

The initial value of the buffer (an empty unicode string by default) can be set by providing *initial\_value*. The *newline* argument works like that of `TextIOWrapper`. The default is to do no newline translation.

`StringIO` provides this method in addition to those from `TextIOWrapper` and its parents:

#### **getvalue()**

Return a unicode containing the entire contents of the buffer at any time before the `StringIO` object's `close()` method is called.

Example usage:

```
import io

output = io.StringIO()
output.write(u'First line.\n')
output.write(u'Second line.\n')

# Retrieve file contents -- this will be
# u'First line.\nSecond line.\n'
contents = output.getvalue()

# Close object and discard memory buffer --
# .getvalue() will now raise an exception.
output.close()
```

**class** `io.IncrementalNewlineDecoder`

A helper codec that decodes newlines for *universal newlines* mode. It inherits `codecs.IncrementalDecoder`.

## 15.2.6 Advanced topics

Here we will discuss several advanced topics pertaining to the concrete I/O implementations described above.

### Performance

#### Binary I/O

By reading and writing only large chunks of data even when the user asks for a single byte, buffered I/O is designed to hide any inefficiency in calling and executing the operating system's unbuffered I/O routines. The gain will vary very much depending on the OS and the kind of I/O which is performed (for example, on some contemporary OSes such as Linux, unbuffered disk I/O can be as fast as buffered I/O). The bottom line, however, is that buffered I/O will offer you

predictable performance regardless of the platform and the backing device. Therefore, it is most always preferable to use buffered I/O rather than unbuffered I/O.

### Text I/O

Text I/O over a binary storage (such as a file) is significantly slower than binary I/O over the same storage, because it implies conversions from unicode to binary data using a character codec. This can become noticeable if you handle huge amounts of text data (for example very large log files). Also, `TextIOWrapper.tell()` and `TextIOWrapper.seek()` are both quite slow due to the reconstruction algorithm used.

`StringIO`, however, is a native in-memory unicode container and will exhibit similar speed to `BytesIO`.

### Multi-threading

`FileIO` objects are thread-safe to the extent that the operating system calls (such as `read(2)` under Unix) they are wrapping are thread-safe too.

Binary buffered objects (instances of `BufferedReader`, `BufferedWriter`, `BufferedRandom` and `BufferedRWPair`) protect their internal structures using a lock; it is therefore safe to call them from multiple threads at once.

`TextIOWrapper` objects are not thread-safe.

### Reentrancy

Binary buffered objects (instances of `BufferedReader`, `BufferedWriter`, `BufferedRandom` and `BufferedRWPair`) are not reentrant. While reentrant calls will not happen in normal situations, they can arise if you are doing I/O in a `signal` handler. If it is attempted to enter a buffered object again while already being accessed *from the same thread*, then a `RuntimeError` is raised.

The above implicitly extends to text files, since the `open()` function will wrap a buffered object inside a `TextIOWrapper`. This includes standard streams and therefore affects the built-in function `print()` as well.

## 15.3 `time` — Time access and conversions

This module provides various time-related functions. For related functionality, see also the `datetime` and `calendar` modules.

Although this module is always available, not all functions are available on all platforms. Most of the functions defined in this module call platform C library functions with the same name. It may sometimes be helpful to consult the platform documentation, because the semantics of these functions varies among platforms.

An explanation of some terminology and conventions is in order.

- The *epoch* is the point where the time starts. On January 1st of that year, at 0 hours, the “time since the epoch” is zero. For Unix, the epoch is 1970. To find out what the epoch is, look at `gmtime(0)`.
- The functions in this module do not handle dates and times before the epoch or far in the future. The cut-off point in the future is determined by the C library; for Unix, it is typically in 2038.
- **Year 2000 (Y2K) issues:** Python depends on the platform’s C library, which generally doesn’t have year 2000 issues, since all dates and times are represented internally as seconds since the epoch. Functions accepting a `struct_time` (see below) generally require a 4-digit year. For backward compatibility, 2-digit years are supported if the module variable `accept2dyear` is a non-zero integer; this variable is initialized to 1 unless

the environment variable `PYTHONY2K` is set to a non-empty string, in which case it is initialized to 0. Thus, you can set

`PYTHONY2K` to a non-empty string in the environment to require 4-digit years for all year input. When 2-digit years are accepted, they are converted according to the POSIX or X/Open standard: values 69-99 are mapped to 1969-1999, and values 0-68 are mapped to 2000-2068. Values 100-1899 are always illegal. Note that this is new as of Python 1.5.2(a2); earlier versions, up to Python 1.5.1 and 1.5.2a1, would add 1900 to year values below 1900.

- UTC is Coordinated Universal Time (formerly known as Greenwich Mean Time, or GMT). The acronym UTC is not a mistake but a compromise between English and French.
- DST is Daylight Saving Time, an adjustment of the timezone by (usually) one hour during part of the year. DST rules are magic (determined by local law) and can change from year to year. The C library has a table containing the local rules (often it is read from a system file for flexibility) and is the only source of True Wisdom in this respect.
- The precision of the various real-time functions may be less than suggested by the units in which their value or argument is expressed. E.g. on most Unix systems, the clock “ticks” only 50 or 100 times a second.
- On the other hand, the precision of `time()` and `sleep()` is better than their Unix equivalents: times are expressed as floating point numbers, `time()` returns the most accurate time available (using `gettimeofday()` where available), and `sleep()` will accept a time with a nonzero fraction (Unix `select()` is used to implement this, where available).
- The time value as returned by `gmtime()`, `localtime()`, and `strptime()`, and accepted by `asctime()`, `mktime()` and `strftime()`, may be considered as a sequence of 9 integers. The return values of `gmtime()`, `localtime()`, and `strptime()` also offer attribute names for individual fields.

See `struct_time` for a description of these objects. Changed in version 2.2: The time value sequence was changed from a tuple to a `struct_time`, with the addition of attribute names for the fields.

- Use the following functions to convert between time representations:

From	To	Use
seconds since the epoch	<code>struct_time</code> in UTC	<code>gmtime()</code>
seconds since the epoch	<code>struct_time</code> in local time	<code>localtime()</code>
<code>struct_time</code> in UTC	seconds since the epoch	<code>calendar.timegm()</code>
<code>struct_time</code> in local time	seconds since the epoch	<code>mktime()</code>

The module defines the following functions and data items:

#### `time.accept2dayear`

Boolean value indicating whether two-digit year values will be accepted. This is true by default, but will be set to false if the environment variable

`PYTHONY2K` has been set to a non-empty string. It may also be modified at run time.

#### `time.altzone`

The offset of the local DST timezone, in seconds west of UTC, if one is defined. This is negative if the local DST timezone is east of UTC (as in Western Europe, including the UK). Only use this if `daylight` is nonzero.

#### `time.asctime([t])`

Convert a tuple or `struct_time` representing a time as returned by `gmtime()` or `localtime()` to a 24-character string of the following form: 'Sun Jun 20 23:21:05 1993'. If `t` is not provided, the current time as returned by `localtime()` is used. Locale information is not used by `asctime()`.

---

**Note:** Unlike the C function of the same name, there is no trailing newline.

---

Changed in version 2.1: Allowed `t` to be omitted.

`time.clock()`

On Unix, return the current processor time as a floating point number expressed in seconds. The precision, and in fact the very definition of the meaning of “processor time”, depends on that of the C function of the same name, but in any case, this is the function to use for benchmarking Python or timing algorithms.

On Windows, this function returns wall-clock seconds elapsed since the first call to this function, as a floating point number, based on the Win32 function `QueryPerformanceCounter()`. The resolution is typically better than one microsecond.

`time.ctime([secs])`

Convert a time expressed in seconds since the epoch to a string representing local time. If *secs* is not provided or `None`, the current time as returned by `time()` is used. `ctime(secs)` is equivalent to `asctime(localtime(secs))`. Locale information is not used by `ctime()`. Changed in version 2.1: Allowed *secs* to be omitted. Changed in version 2.4: If *secs* is `None`, the current time is used.

`time.daylight`

Nonzero if a DST timezone is defined.

`time.gmtime([secs])`

Convert a time expressed in seconds since the epoch to a `struct_time` in UTC in which the `dst` flag is always zero. If *secs* is not provided or `None`, the current time as returned by `time()` is used. Fractions of a second are ignored. See above for a description of the `struct_time` object. See `calendar.timegm()` for the inverse of this function. Changed in version 2.1: Allowed *secs* to be omitted. Changed in version 2.4: If *secs* is `None`, the current time is used.

`time.localtime([secs])`

Like `gmtime()` but converts to local time. If *secs* is not provided or `None`, the current time as returned by `time()` is used. The `dst` flag is set to 1 when DST applies to the given time. Changed in version 2.1: Allowed *secs* to be omitted. Changed in version 2.4: If *secs* is `None`, the current time is used.

`time.mktime(t)`

This is the inverse function of `localtime()`. Its argument is the `struct_time` or full 9-tuple (since the `dst` flag is needed; use `-1` as the `dst` flag if it is unknown) which expresses the time in *local* time, not UTC. It returns a floating point number, for compatibility with `time()`. If the input value cannot be represented as a valid time, either `OverflowError` or `ValueError` will be raised (which depends on whether the invalid value is caught by Python or the underlying C libraries). The earliest date for which it can generate a time is platform-dependent.

`time.sleep(secs)`

Suspend execution for the given number of seconds. The argument may be a floating point number to indicate a more precise sleep time. The actual suspension time may be less than that requested because any caught signal will terminate the `sleep()` following execution of that signal’s catching routine. Also, the suspension time may be longer than requested by an arbitrary amount because of the scheduling of other activity in the system.

`time.strftime(format[, t])`

Convert a tuple or `struct_time` representing a time as returned by `gmtime()` or `localtime()` to a string as specified by the *format* argument. If *t* is not provided, the current time as returned by `localtime()` is used. *format* must be a string. `ValueError` is raised if any field in *t* is outside of the allowed range. Changed in version 2.1: Allowed *t* to be omitted. Changed in version 2.4: `ValueError` raised if a field in *t* is out of range. Changed in version 2.5: 0 is now a legal argument for any position in the time tuple; if it is normally illegal the value is forced to a correct one.. The following directives can be embedded in the *format* string. They are shown without the optional field width and precision specification, and are replaced by the indicated characters in the `strftime()` result:

Directive	Meaning	Notes
%a	Locale's abbreviated weekday name.	
%A	Locale's full weekday name.	
%b	Locale's abbreviated month name.	
%B	Locale's full month name.	
%c	Locale's appropriate date and time representation.	
%d	Day of the month as a decimal number [01,31].	
%H	Hour (24-hour clock) as a decimal number [00,23].	
%I	Hour (12-hour clock) as a decimal number [01,12].	
%j	Day of the year as a decimal number [001,366].	
%m	Month as a decimal number [01,12].	
%M	Minute as a decimal number [00,59].	
%p	Locale's equivalent of either AM or PM.	(1)
%S	Second as a decimal number [00,61].	(2)
%U	Week number of the year (Sunday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Sunday are considered to be in week 0.	(3)
%w	Weekday as a decimal number [0(Sunday),6].	
%W	Week number of the year (Monday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Monday are considered to be in week 0.	(3)
%x	Locale's appropriate date representation.	
%X	Locale's appropriate time representation.	
%y	Year without century as a decimal number [00,99].	
%Y	Year with century as a decimal number.	
%Z	Time zone name (no characters if no time zone exists).	
%%	A literal '%' character.	

Notes:

1. When used with the `strptime()` function, the `%p` directive only affects the output hour field if the `%I` directive is used to parse the hour.
2. The range really is 0 to 61; this accounts for leap seconds and the (very rare) double leap seconds.
3. When used with the `strptime()` function, `%U` and `%W` are only used in calculations when the day of the week and the year are specified.

Here is an example, a format for dates compatible with that specified in the

**RFC 2822** Internet email standard.<sup>1</sup>

```
>>> from time import gmtime, strftime
>>> strftime("%a, %d %b %Y %H:%M:%S +0000", gmtime())
'Thu, 28 Jun 2001 14:17:15 +0000'
```

Additional directives may be supported on certain platforms, but only the ones listed here have a meaning standardized by ANSI C.

On some platforms, an optional field width and precision specification can immediately follow the initial '%' of a directive in the following order; this is also not portable. The field width is normally 2 except for `%j` where it is 3.

<sup>1</sup> The use of `%Z` is now deprecated, but the `%z` escape that expands to the preferred hour/minute offset is not supported by all ANSI C libraries. Also, a strict reading of the original 1982 **RFC 822** standard calls for a two-digit year (`%y` rather than `%Y`), but practice moved to 4-digit years long before the year 2000. After that, **RFC 822** became obsolete and the 4-digit year has been first recommended by **RFC 1123** and then mandated by **RFC 2822**.

`time.strptime(string[, format])`

Parse a string representing a time according to a format. The return value is a `struct_time` as returned by `gmtime()` or `localtime()`.

The `format` parameter uses the same directives as those used by `strftime()`; it defaults to `"%a %b %d %H:%M:%S %Y"` which matches the formatting returned by `ctime()`. If `string` cannot be parsed according to `format`, or if it has excess data after parsing, `ValueError` is raised. The default values used to fill in any missing data when more accurate values cannot be inferred are (1900, 1, 1, 0, 0, 0, 0, 1, -1).

For example:

```
>>> import time
>>> time.strptime("30 Nov 00", "%d %b %y")
time.struct_time(tm_year=2000, tm_mon=11, tm_mday=30, tm_hour=0, tm_min=0,
                 tm_sec=0, tm_wday=3, tm_yday=335, tm_isdst=-1)
```

Support for the `%Z` directive is based on the values contained in `tzname` and whether `daylight` is true. Because of this, it is platform-specific except for recognizing UTC and GMT which are always known (and are considered to be non-daylight savings timezones).

Only the directives specified in the documentation are supported. Because `strftime()` is implemented per platform it can sometimes offer more directives than those listed. But `strptime()` is independent of any platform and thus does not necessarily support all directives available that are not documented as supported.

**class** `time.struct_time`

The type of the time value sequence returned by `gmtime()`, `localtime()`, and `strptime()`. It is an object with a *named tuple* interface: values can be accessed by index and by attribute name. The following values are present:

Index	Attribute	Values
0	<code>tm_year</code>	(for example, 1993)
1	<code>tm_mon</code>	range [1, 12]
2	<code>tm_mday</code>	range [1, 31]
3	<code>tm_hour</code>	range [0, 23]
4	<code>tm_min</code>	range [0, 59]
5	<code>tm_sec</code>	range [0, 61]; see (2) in <code>strftime()</code> description
6	<code>tm_wday</code>	range [0, 6], Monday is 0
7	<code>tm_yday</code>	range [1, 366]
8	<code>tm_isdst</code>	0, 1 or -1; see below

New in version 2.2. Note that unlike the C structure, the month value is a range of [1, 12], not [0, 11]. A year value will be handled as described under *Year 2000 (Y2K) issues* above. A `-1` argument as the daylight savings flag, passed to `mktime()` will usually result in the correct daylight savings state to be filled in.

When a tuple with an incorrect length is passed to a function expecting a `struct_time`, or having elements of the wrong type, a `TypeError` is raised.

`time.time()`

Return the time in seconds since the epoch as a floating point number. Note that even though the time is always returned as a floating point number, not all systems provide time with a better precision than 1 second. While this function normally returns non-decreasing values, it can return a lower value than a previous call if the system clock has been set back between the two calls.

`time.timezone`

The offset of the local (non-DST) timezone, in seconds west of UTC (negative in most of Western Europe, positive in the US, zero in the UK).

`time.tzname`

A tuple of two strings: the first is the name of the local non-DST timezone, the second is the name of the local DST timezone. If no DST timezone is defined, the second string should not be used.

`time.tzset()`

Resets the time conversion rules used by the library routines. The environment variable TZ specifies how this is done. New in version 2.3. Availability: Unix.

---

**Note:** Although in many cases, changing the TZ environment variable may affect the output of functions like `localtime()` without calling `tzset()`, this behavior should not be relied on.

The TZ environment variable should contain no whitespace.

---

The standard format of the TZ environment variable is (whitespace added for clarity):

```
std offset [dst [offset [,start[/time], end[/time]]]]
```

Where the components are:

**std and dst** Three or more alphanumerics giving the timezone abbreviations. These will be propagated into `time.tzname`

**offset** The offset has the form:  $\pm$  hh[:mm[:ss]]. This indicates the value added the local time to arrive at UTC. If preceded by a '-', the timezone is east of the Prime Meridian; otherwise, it is west. If no offset follows dst, summer time is assumed to be one hour ahead of standard time.

**start[/time], end[/time]** Indicates when to change to and back from DST. The format of the start and end dates are one of the following:

‘**Jn**’ The Julian day  $n$  ( $1 \leq n \leq 365$ ). Leap days are not counted, so in all years February 28 is day 59 and March 1 is day 60.

‘**n**’ The zero-based Julian day ( $0 \leq n \leq 365$ ). Leap days are counted, and it is possible to refer to February 29.

‘**Mm.n.d**’ The  $d$ ’th day ( $0 \leq d \leq 6$ ) or week  $n$  of month  $m$  of the year ( $1 \leq n \leq 5$ ,  $1 \leq m \leq 12$ , where week 5 means “the last  $d$  day in month  $m$ ” which may occur in either the fourth or the fifth week). Week 1 is the first week in which the  $d$ ’th day occurs. Day zero is Sunday.

`time` has the same format as `offset` except that no leading sign ('-' or '+') is allowed. The default, if time is not given, is 02:00:00.

```
>>> os.environ['TZ'] = 'EST+05EDT,M4.1.0,M10.5.0'
>>> time.tzset()
>>> time.strftime('%X %x %Z')
'02:07:36 05/08/03 EDT'
>>> os.environ['TZ'] = 'AEST-10AEDT-11,M10.5.0,M3.5.0'
>>> time.tzset()
>>> time.strftime('%X %x %Z')
'16:08:12 05/08/03 AEST'
```

On many Unix systems (including \*BSD, Linux, Solaris, and Darwin), it is more convenient to use the system’s zoneinfo (`tzfile(5)`) database to specify the timezone rules. To do this, set the TZ environment variable to the path of the required timezone datafile, relative to the root of the systems ‘zoneinfo’ timezone database, usually located at `/usr/share/zoneinfo`. For example, ‘`US/Eastern`’, ‘`Australia/Melbourne`’, ‘`Egypt`’ or ‘`Europe/Amsterdam`’.

```
>>> os.environ['TZ'] = 'US/Eastern'
>>> time.tzset()
>>> time.tzname
('EST', 'EDT')
>>> os.environ['TZ'] = 'Egypt'
>>> time.tzset()
>>> time.tzname
('EET', 'EEST')
```

**See Also:**

**Module `datetime`** More object-oriented interface to dates and times.

**Module `locale`** Internationalization services. The locale settings can affect the return values for some of the functions in the `time` module.

**Module `calendar`** General calendar-related functions. `timegm()` is the inverse of `gmtime()` from this module.

## 15.4 `argparse` — Parser for command-line options, arguments and sub-commands

New in version 2.7. **Source code:** [Lib/argparse.py](#)

### Tutorial

This page contains the API reference information. For a more gentle introduction to Python command-line parsing, have a look at the *argparse tutorial*.

The `argparse` module makes it easy to write user-friendly command-line interfaces. The program defines what arguments it requires, and `argparse` will figure out how to parse those out of `sys.argv`. The `argparse` module also automatically generates help and usage messages and issues errors when users give the program invalid arguments.

### 15.4.1 Example

The following code is a Python program that takes a list of integers and produces either the sum or the max:

```
import argparse
```

```
parser = argparse.ArgumentParser(description='Process some integers.')
parser.add_argument('integers', metavar='N', type=int, nargs='+',
                    help='an integer for the accumulator')
parser.add_argument('--sum', dest='accumulate', action='store_const',
                    const=sum, default=max,
                    help='sum the integers (default: find the max)')
```

```
args = parser.parse_args()
print args.accumulate(args.integers)
```

Assuming the Python code above is saved into a file called `prog.py`, it can be run at the command line and provides useful help messages:

```
$ prog.py -h
usage: prog.py [-h] [--sum] N [N ...]
```

Process some integers.

```
positional arguments:
  N            an integer for the accumulator
```

```
optional arguments:
  -h, --help  show this help message and exit
  --sum       sum the integers (default: find the max)
```

When run with the appropriate arguments, it prints either the sum or the max of the command-line integers:

```
$ prog.py 1 2 3 4
4
```

```
$ prog.py 1 2 3 4 --sum
10
```

If invalid arguments are passed in, it will issue an error:

```
$ prog.py a b c
usage: prog.py [-h] [--sum] N [N ...]
prog.py: error: argument N: invalid int value: 'a'
```

The following sections walk you through this example.

## Creating a parser

The first step in using the `argparse` is creating an `ArgumentParser` object:

```
>>> parser = argparse.ArgumentParser(description='Process some integers.')
```

The `ArgumentParser` object will hold all the information necessary to parse the command line into Python data types.

## Adding arguments

Filling an `ArgumentParser` with information about program arguments is done by making calls to the `add_argument()` method. Generally, these calls tell the `ArgumentParser` how to take the strings on the command line and turn them into objects. This information is stored and used when `parse_args()` is called. For example:

```
>>> parser.add_argument('integers', metavar='N', type=int, nargs='+',
...                     help='an integer for the accumulator')
>>> parser.add_argument('--sum', dest='accumulate', action='store_const',
...                     const=sum, default=max,
...                     help='sum the integers (default: find the max)')
```

Later, calling `parse_args()` will return an object with two attributes, `integers` and `accumulate`. The `integers` attribute will be a list of one or more ints, and the `accumulate` attribute will be either the `sum()` function, if `--sum` was specified at the command line, or the `max()` function if it was not.

## Parsing arguments

`ArgumentParser` parses arguments through the `parse_args()` method. This will inspect the command line, convert each argument to the appropriate type and then invoke the appropriate action. In most cases, this means a simple `Namespace` object will be built up from attributes parsed out of the command line:

```
>>> parser.parse_args(['--sum', '7', '-1', '42'])
Namespace(accumulate=<built-in function sum>, integers=[7, -1, 42])
```

In a script, `parse_args()` will typically be called with no arguments, and the `ArgumentParser` will automatically determine the command-line arguments from `sys.argv`.

### 15.4.2 ArgumentParser objects

```
class argparse.ArgumentParser (prog=None, usage=None, description=None, epilog=None, parents=[], formatter_class=argparse.HelpFormatter, prefix_chars='-', fromfile_prefix_chars=None, argument_default=None, conflict_handler='error', add_help=True)
```

Create a new `ArgumentParser` object. Each parameter has its own more detailed description below, but in short they are:

- `description` - Text to display before the argument help.
- `epilog` - Text to display after the argument help.
- `add_help` - Add a `-h/--help` option to the parser. (default: `True`)
- `argument_default` - Set the global default value for arguments. (default: `None`)
- `parents` - A list of `ArgumentParser` objects whose arguments should also be included.
- `prefix_chars` - The set of characters that prefix optional arguments. (default: `'-'`)
- `fromfile_prefix_chars` - The set of characters that prefix files from which additional arguments should be read. (default: `None`)
- `formatter_class` - A class for customizing the help output.
- `conflict_handler` - Usually unnecessary, defines strategy for resolving conflicting optionals.
- `prog` - The name of the program (default: `sys.argv[0]`)
- `usage` - The string describing the program usage (default: generated)

The following sections describe how each of these are used.

#### description

Most calls to the `ArgumentParser` constructor will use the `description=` keyword argument. This argument gives a brief description of what the program does and how it works. In help messages, the description is displayed between the command-line usage string and the help messages for the various arguments:

```
>>> parser = argparse.ArgumentParser(description='A foo that bars')
>>> parser.print_help()
usage: argparse.py [-h]
```

```
A foo that bars
```

```
optional arguments:
```

```
-h, --help show this help message and exit
```

By default, the description will be line-wrapped so that it fits within the given space. To change this behavior, see the `formatter_class` argument.

## epilog

Some programs like to display additional description of the program after the description of the arguments. Such text can be specified using the `epilog=` argument to `ArgumentParser`:

```
>>> parser = argparse.ArgumentParser(
...     description='A foo that bars',
...     epilog="And that's how you'd foo a bar")
>>> parser.print_help()
usage: argparse.py [-h]
```

```
A foo that bars
```

```
optional arguments:
  -h, --help  show this help message and exit
```

```
And that's how you'd foo a bar
```

As with the `description` argument, the `epilog=` text is by default line-wrapped, but this behavior can be adjusted with the `formatter_class` argument to `ArgumentParser`.

## add\_help

By default, `ArgumentParser` objects add an option which simply displays the parser's help message. For example, consider a file named `myprogram.py` containing the following code:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```

If `-h` or `--help` is supplied at the command line, the `ArgumentParser` help will be printed:

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo FOO   foo help
```

Occasionally, it may be useful to disable the addition of this help option. This can be achieved by passing `False` as the `add_help=` argument to `ArgumentParser`:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> parser.add_argument('--foo', help='foo help')
>>> parser.print_help()
usage: PROG [--foo FOO]
```

```
optional arguments:
  --foo FOO   foo help
```

The help option is typically `-h/--help`. The exception to this is if the `prefix_chars=` is specified and does not include `-`, in which case `-h` and `--help` are not valid options. In this case, the first character in `prefix_chars` is used to prefix the help options:

```
>>> parser = argparse.ArgumentParser(prog='PROG', prefix_chars='+/')
>>> parser.print_help()
usage: PROG [+h]
```

```
optional arguments:
  +h, ++help  show this help message and exit
```

### prefix\_chars

Most command-line options will use `-` as the prefix, e.g. `-f/--foo`. Parsers that need to support different or additional prefix characters, e.g. for options like `+f` or `/foo`, may specify them using the `prefix_chars=` argument to the `ArgumentParser` constructor:

```
>>> parser = argparse.ArgumentParser(prog='PROG', prefix_chars='+-')
>>> parser.add_argument('+f')
>>> parser.add_argument('++bar')
>>> parser.parse_args('+f X ++bar Y'.split())
Namespace(bar='Y', f='X')
```

The `prefix_chars=` argument defaults to `'-'`. Supplying a set of characters that does not include `-` will cause `-f/--foo` options to be disallowed.

### fromfile\_prefix\_chars

Sometimes, for example when dealing with a particularly long argument lists, it may make sense to keep the list of arguments in a file rather than typing it out at the command line. If the `fromfile_prefix_chars=` argument is given to the `ArgumentParser` constructor, then arguments that start with any of the specified characters will be treated as files, and will be replaced by the arguments they contain. For example:

```
>>> with open('args.txt', 'w') as fp:
...     fp.write('-f\nbar')
>>> parser = argparse.ArgumentParser(fromfile_prefix_chars='@')
>>> parser.add_argument('-f')
>>> parser.parse_args(['-f', 'foo', '@args.txt'])
Namespace(f='bar')
```

Arguments read from a file must by default be one per line (but see also `convert_arg_line_to_args()`) and are treated as if they were in the same place as the original file referencing argument on the command line. So in the example above, the expression `['-f', 'foo', '@args.txt']` is considered equivalent to the expression `['-f', 'foo', '-f', 'bar']`.

The `fromfile_prefix_chars=` argument defaults to `None`, meaning that arguments will never be treated as file references.

### argument\_default

Generally, argument defaults are specified either by passing a default to `add_argument()` or by calling the `set_defaults()` methods with a specific set of name-value pairs. Sometimes however, it may be useful to specify a single parser-wide default for arguments. This can be accomplished by passing the `argument_default=` keyword argument to `ArgumentParser`. For example, to globally suppress attribute creation on `parse_args()` calls, we supply `argument_default=SUPPRESS`:

```
>>> parser = argparse.ArgumentParser(argument_default=argparse.SUPPRESS)
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar', nargs='?')
```

```
>>> parser.parse_args(['--foo', '1', 'BAR'])
Namespace(bar='BAR', foo='1')
>>> parser.parse_args([])
Namespace()
```

## parents

Sometimes, several parsers share a common set of arguments. Rather than repeating the definitions of these arguments, a single parser with all the shared arguments and passed to `parents=` argument to `ArgumentParser` can be used. The `parents=` argument takes a list of `ArgumentParser` objects, collects all the positional and optional actions from them, and adds these actions to the `ArgumentParser` object being constructed:

```
>>> parent_parser = argparse.ArgumentParser(add_help=False)
>>> parent_parser.add_argument('--parent', type=int)

>>> foo_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> foo_parser.add_argument('foo')
>>> foo_parser.parse_args(['--parent', '2', 'XXX'])
Namespace(foo='XXX', parent=2)

>>> bar_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> bar_parser.add_argument('--bar')
>>> bar_parser.parse_args(['--bar', 'YYY'])
Namespace(bar='YYY', parent=None)
```

Note that most parent parsers will specify `add_help=False`. Otherwise, the `ArgumentParser` will see two `-h/--help` options (one in the parent and one in the child) and raise an error.

---

**Note:** You must fully initialize the parsers before passing them via `parents=`. If you change the parent parsers after the child parser, those changes will not be reflected in the child.

---

## formatter\_class

`ArgumentParser` objects allow the help formatting to be customized by specifying an alternate formatting class. Currently, there are three such classes:

```
class argparse.RawDescriptionHelpFormatter
class argparse.RawTextHelpFormatter
class argparse.ArgumentDefaultsHelpFormatter
```

The first two allow more control over how textual descriptions are displayed, while the last automatically adds information about argument default values.

By default, `ArgumentParser` objects line-wrap the `description` and `epilog` texts in command-line help messages:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     description='''this description
...         was indented weird
...         but that is okay''',
...     epilog='''
...         likewise for this epilog whose whitespace will
...         be cleaned up and whose words will be wrapped
...         across a couple lines''')
```

```
>>> parser.print_help()
usage: PROG [-h]
```

this description was indented weird but that is okay

```
optional arguments:
  -h, --help  show this help message and exit
```

likewise for this epilog whose whitespace will be cleaned up and whose words will be wrapped across a couple lines

Passing `RawDescriptionHelpFormatter` as `formatter_class=` indicates that `description` and `epilog` are already correctly formatted and should not be line-wrapped:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.RawDescriptionHelpFormatter,
...     description=textwrap.dedent("""\
...         Please do not mess up this text!
...         -----
...         I have indented it
...         exactly the way
...         I want it
...     """))
>>> parser.print_help()
usage: PROG [-h]
```

```
Please do not mess up this text!
-----
    I have indented it
    exactly the way
    I want it
```

```
optional arguments:
  -h, --help  show this help message and exit
```

`RawTextHelpFormatter` maintains whitespace for all sorts of help text, including argument descriptions.

The other formatter class available, `ArgumentDefaultsHelpFormatter`, will add information about the default value of each of the arguments:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.ArgumentDefaultsHelpFormatter)
>>> parser.add_argument('--foo', type=int, default=42, help='FOO!')
>>> parser.add_argument('bar', nargs='*', default=[1, 2, 3], help='BAR!')
>>> parser.print_help()
usage: PROG [-h] [--foo FOO] [bar [bar ...]]
```

```
positional arguments:
  bar          BAR! (default: [1, 2, 3])
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo FOO   FOO! (default: 42)
```

## conflict\_handler

`ArgumentParser` objects do not allow two actions with the same option string. By default, `ArgumentParser` objects raises an exception if an attempt is made to create an argument with an option string that is already in use:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
Traceback (most recent call last):
  ..
ArgumentError: argument --foo: conflicting option string(s): --foo
```

Sometimes (e.g. when using `parents`) it may be useful to simply override any older arguments with the same option string. To get this behavior, the value `'resolve'` can be supplied to the `conflict_handler=` argument of `ArgumentParser`:

```
>>> parser = argparse.ArgumentParser(prog='PROG', conflict_handler='resolve')
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
>>> parser.print_help()
usage: PROG [-h] [-f FOO] [--foo FOO]
```

```
optional arguments:
  -h, --help  show this help message and exit
  -f FOO      old foo help
  --foo FOO   new foo help
```

Note that `ArgumentParser` objects only remove an action if all of its option strings are overridden. So, in the example above, the old `-f/--foo` action is retained as the `-f` action, because only the `--foo` option string was overridden.

## prog

By default, `ArgumentParser` objects uses `sys.argv[0]` to determine how to display the name of the program in help messages. This default is almost always desirable because it will make the help messages match how the program was invoked on the command line. For example, consider a file named `myprogram.py` with the following code:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```

The help for this program will display `myprogram.py` as the program name (regardless of where the program was invoked from):

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
  -h, --help  show this help message and exit
  --foo FOO   foo help
$ cd ..
$ python subdir\myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
```

```
-h, --help  show this help message and exit
--foo FOO   foo help
```

To change this default behavior, another value can be supplied using the `prog=` argument to `ArgumentParser`:

```
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.print_help()
usage: myprogram [-h]
```

```
optional arguments:
  -h, --help  show this help message and exit
```

Note that the program name, whether determined from `sys.argv[0]` or from the `prog=` argument, is available to help messages using the `%(prog)s` format specifier.

```
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.add_argument('--foo', help='foo of the %(prog)s program')
>>> parser.print_help()
usage: myprogram [-h] [--foo FOO]
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo FOO   foo of the myprogram program
```

### usage

By default, `ArgumentParser` calculates the usage message from the arguments it contains:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', nargs='?', help='foo help')
>>> parser.add_argument('bar', nargs='+', help='bar help')
>>> parser.print_help()
usage: PROG [-h] [--foo [FOO]] bar [bar ...]
```

```
positional arguments:
  bar                bar help
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo [FOO]  foo help
```

The default message can be overridden with the `usage=` keyword argument:

```
>>> parser = argparse.ArgumentParser(prog='PROG', usage='%(prog)s [options]')
>>> parser.add_argument('--foo', nargs='?', help='foo help')
>>> parser.add_argument('bar', nargs='+', help='bar help')
>>> parser.print_help()
usage: PROG [options]
```

```
positional arguments:
  bar                bar help
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo [FOO]  foo help
```

The `%(prog)s` format specifier is available to fill in the program name in your usage messages.

### 15.4.3 The `add_argument()` method

`ArgumentParser.add_argument` (*name or flags...* [, *action*] [, *nargs*] [, *const*] [, *default*] [, *type*] [, *choices*] [, *required*] [, *help*] [, *metavar*] [, *dest*])

Define how a single command-line argument should be parsed. Each parameter has its own more detailed description below, but in short they are:

- **name or flags** - Either a name or a list of option strings, e.g. `foo` or `-f`, `--foo`.
- **action** - The basic type of action to be taken when this argument is encountered at the command line.
- **nargs** - The number of command-line arguments that should be consumed.
- **const** - A constant value required by some **action** and **nargs** selections.
- **default** - The value produced if the argument is absent from the command line.
- **type** - The type to which the command-line argument should be converted.
- **choices** - A container of the allowable values for the argument.
- **required** - Whether or not the command-line option may be omitted (optionals only).
- **help** - A brief description of what the argument does.
- **metavar** - A name for the argument in usage messages.
- **dest** - The name of the attribute to be added to the object returned by `parse_args()`.

The following sections describe how each of these are used.

#### name or flags

The `add_argument()` method must know whether an optional argument, like `-f` or `--foo`, or a positional argument, like a list of filenames, is expected. The first arguments passed to `add_argument()` must therefore be either a series of flags, or a simple argument name. For example, an optional argument could be created like:

```
>>> parser.add_argument('-f', '--foo')
```

while a positional argument could be created like:

```
>>> parser.add_argument('bar')
```

When `parse_args()` is called, optional arguments will be identified by the `-` prefix, and the remaining arguments will be assumed to be positional:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args(['BAR'])
Namespace(bar='BAR', foo=None)
>>> parser.parse_args(['BAR', '--foo', 'FOO'])
Namespace(bar='BAR', foo='FOO')
>>> parser.parse_args(['--foo', 'FOO'])
usage: PROG [-h] [-f FOO] bar
PROG: error: too few arguments
```

#### action

`ArgumentParser` objects associate command-line arguments with actions. These actions can do just about anything with the command-line arguments associated with them, though most actions simply add an attribute to the object

returned by `parse_args()`. The `action` keyword argument specifies how the command-line arguments should be handled. The supported actions are:

- `'store'` - This just stores the argument's value. This is the default action. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.parse_args('--foo 1'.split())
Namespace(foo='1')
```

- `'store_const'` - This stores the value specified by the `const` keyword argument. (Note that the `const` keyword argument defaults to the rather unhelpful `None`.) The `'store_const'` action is most commonly used with optional arguments that specify some sort of flag. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_const', const=42)
>>> parser.parse_args('--foo'.split())
Namespace(foo=42)
```

- `'store_true'` and `'store_false'` - These are special cases of `'store_const'` using for storing the values `True` and `False` respectively. In addition, they create default values of `False` and `True` respectively. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_true')
>>> parser.add_argument('--bar', action='store_false')
>>> parser.add_argument('--baz', action='store_false')
>>> parser.parse_args('--foo --bar'.split())
Namespace(bar=False, baz=True, foo=True)
```

- `'append'` - This stores a list, and appends each argument value to the list. This is useful to allow an option to be specified multiple times. Example usage:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='append')
>>> parser.parse_args('--foo 1 --foo 2'.split())
Namespace(foo=['1', '2'])
```

- `'append_const'` - This stores a list, and appends the value specified by the `const` keyword argument to the list. (Note that the `const` keyword argument defaults to `None`.) The `'append_const'` action is typically useful when multiple arguments need to store constants to the same list. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--str', dest='types', action='append_const', const=str)
>>> parser.add_argument('--int', dest='types', action='append_const', const=int)
>>> parser.parse_args('--str --int'.split())
Namespace(types=[<type 'str'>, <type 'int'>])
```

- `'count'` - This counts the number of times a keyword argument occurs. For example, this is useful for increasing verbosity levels:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--verbose', '-v', action='count')
>>> parser.parse_args('-vvv'.split())
Namespace(verbose=3)
```

- `'help'` - This prints a complete help message for all the options in the current parser and then exits. By default a help action is automatically added to the parser. See `ArgumentParser` for details of how the output is created.

- 'version' - This expects a version= keyword argument in the `add_argument()` call, and prints version information and exits when invoked:

```
>>> import argparse
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--version', action='version', version='%(prog)s 2.0')
>>> parser.parse_args(['--version'])
PROG 2.0
```

You can also specify an arbitrary action by passing an object that implements the Action API. The easiest way to do this is to extend `argparse.Action`, supplying an appropriate `__call__` method. The `__call__` method should accept four parameters:

- `parser` - The `ArgumentParser` object which contains this action.
- `namespace` - The `Namespace` object that will be returned by `parse_args()`. Most actions add an attribute to this object.
- `values` - The associated command-line arguments, with any type conversions applied. (Type conversions are specified with the `type` keyword argument to `add_argument()`.)
- `option_string` - The option string that was used to invoke this action. The `option_string` argument is optional, and will be absent if the action is associated with a positional argument.

An example of a custom action:

```
>>> class FooAction(argparse.Action):
...     def __call__(self, parser, namespace, values, option_string=None):
...         print '%r %r %r' % (namespace, values, option_string)
...         setattr(namespace, self.dest, values)
...
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action=FooAction)
>>> parser.add_argument('bar', action=FooAction)
>>> args = parser.parse_args('1 --foo 2'.split())
Namespace(bar=None, foo=None) '1' None
Namespace(bar='1', foo=None) '2' '--foo'
>>> args
Namespace(bar='1', foo='2')
```

## nargs

`ArgumentParser` objects usually associate a single command-line argument with a single action to be taken. The `nargs` keyword argument associates a different number of command-line arguments with a single action. The supported values are:

- `N` (an integer). `N` arguments from the command line will be gathered together into a list. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', nargs=2)
>>> parser.add_argument('bar', nargs=1)
>>> parser.parse_args('c --foo a b'.split())
Namespace(bar=['c'], foo=['a', 'b'])
```

Note that `nargs=1` produces a list of one item. This is different from the default, in which the item is produced by itself.

- `'?'`. One argument will be consumed from the command line if possible, and produced as a single item. If no command-line argument is present, the value from `default` will be produced. Note that for optional arguments,

there is an additional case - the option string is present but not followed by a command-line argument. In this case the value from `const` will be produced. Some examples to illustrate this:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', nargs='?', const='c', default='d')
>>> parser.add_argument('bar', nargs='?', default='d')
>>> parser.parse_args('XX --foo YY'.split())
Namespace(bar='XX', foo='YY')
>>> parser.parse_args('XX --foo'.split())
Namespace(bar='XX', foo='c')
>>> parser.parse_args('').split())
Namespace(bar='d', foo='d')
```

One of the more common uses of `nargs='?'` is to allow optional input and output files:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('infile', nargs='?', type=argparse.FileType('r'),
...                   default=sys.stdin)
>>> parser.add_argument('outfile', nargs='?', type=argparse.FileType('w'),
...                   default=sys.stdout)
>>> parser.parse_args(['input.txt', 'output.txt'])
Namespace(infile=<open file 'input.txt', mode 'r' at 0x...>,
          outfile=<open file 'output.txt', mode 'w' at 0x...>)
>>> parser.parse_args([])
Namespace(infile=<open file '<stdin>', mode 'r' at 0x...>,
          outfile=<open file '<stdout>', mode 'w' at 0x...>)
```

- `'*'`. All command-line arguments present are gathered into a list. Note that it generally doesn't make much sense to have more than one positional argument with `nargs='*'`, but multiple optional arguments with `nargs='*'` is possible. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', nargs='*')
>>> parser.add_argument('--bar', nargs='*')
>>> parser.add_argument('baz', nargs='*')
>>> parser.parse_args('a b --foo x y --bar 1 2'.split())
Namespace(bar=['1', '2'], baz=['a', 'b'], foo=['x', 'y'])
```

- `'+'`. Just like `'*'`, all command-line args present are gathered into a list. Additionally, an error message will be generated if there wasn't at least one command-line argument present. For example:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', nargs='+')
>>> parser.parse_args('a b'.split())
Namespace(foo=['a', 'b'])
>>> parser.parse_args('').split())
usage: PROG [-h] foo [foo ...]
PROG: error: too few arguments
```

- `argparse.REMAINDER`. All the remaining command-line arguments are gathered into a list. This is commonly useful for command line utilities that dispatch to other command line utilities:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo')
>>> parser.add_argument('command')
>>> parser.add_argument('args', nargs=argparse.REMAINDER)
>>> print parser.parse_args('--foo B cmd --arg1 XX ZZ'.split())
Namespace(args=['--arg1', 'XX', 'ZZ'], command='cmd', foo='B')
```

If the `nargs` keyword argument is not provided, the number of arguments consumed is determined by the `action`. Generally this means a single command-line argument will be consumed and a single item (not a list) will be produced.

## const

The `const` argument of `add_argument()` is used to hold constant values that are not read from the command line but are required for the various `ArgumentParser` actions. The two most common uses of it are:

- When `add_argument()` is called with `action='store_const'` or `action='append_const'`. These actions add the `const` value to one of the attributes of the object returned by `parse_args()`. See the `action` description for examples.
- When `add_argument()` is called with option strings (like `-f` or `--foo`) and `nargs='?'`. This creates an optional argument that can be followed by zero or one command-line arguments. When parsing the command line, if the option string is encountered with no command-line argument following it, the value of `const` will be assumed instead. See the `nargs` description for examples.

The `const` keyword argument defaults to `None`.

## default

All optional arguments and some positional arguments may be omitted at the command line. The `default` keyword argument of `add_argument()`, whose value defaults to `None`, specifies what value should be used if the command-line argument is not present. For optional arguments, the `default` value is used when the option string was not present at the command line:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default=42)
>>> parser.parse_args('--foo 2'.split())
Namespace(foo='2')
>>> parser.parse_args('').split())
Namespace(foo=42)
```

For positional arguments with `nargs` equal to `?` or `*`, the `default` value is used when no command-line argument was present:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', nargs='?', default=42)
>>> parser.parse_args('a'.split())
Namespace(foo='a')
>>> parser.parse_args('').split())
Namespace(foo=42)
```

Providing `default=argparse.SUPPRESS` causes no attribute to be added if the command-line argument was not present.:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default=argparse.SUPPRESS)
>>> parser.parse_args([])
Namespace()
>>> parser.parse_args(['--foo', '1'])
Namespace(foo='1')
```

## type

By default, `ArgumentParser` objects read command-line arguments in as simple strings. However, quite often the command-line string should instead be interpreted as another type, like a `float` or `int`. The `type` keyword argument of `add_argument()` allows any necessary type-checking and type conversions to be performed. Common built-in types and functions can be used directly as the value of the `type` argument:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.add_argument('bar', type=file)
>>> parser.parse_args('2 temp.txt'.split())
Namespace(bar=<open file 'temp.txt', mode 'r' at 0x...>, foo=2)
```

To ease the use of various types of files, the `argparse` module provides the factory `FileType` which takes the `mode=` and `bufsize=` arguments of the file object. For example, `FileType('w')` can be used to create a writable file:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar', type=argparse.FileType('w'))
>>> parser.parse_args(['out.txt'])
Namespace(bar=<open file 'out.txt', mode 'w' at 0x...>)
```

`type=` can take any callable that takes a single string argument and returns the converted value:

```
>>> def perfect_square(string):
...     value = int(string)
...     sqrt = math.sqrt(value)
...     if sqrt != int(sqrt):
...         msg = "%r is not a perfect square" % string
...         raise argparse.ArgumentTypeError(msg)
...     return value
...
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=perfect_square)
>>> parser.parse_args('9'.split())
Namespace(foo=9)
>>> parser.parse_args('7'.split())
usage: PROG [-h] foo
PROG: error: argument foo: '7' is not a perfect square
```

The `choices` keyword argument may be more convenient for type checkers that simply check against a range of values:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=int, choices=xrange(5, 10))
>>> parser.parse_args('7'.split())
Namespace(foo=7)
>>> parser.parse_args('11'.split())
usage: PROG [-h] {5,6,7,8,9}
PROG: error: argument foo: invalid choice: 11 (choose from 5, 6, 7, 8, 9)
```

See the `choices` section for more details.

## choices

Some command-line arguments should be selected from a restricted set of values. These can be handled by passing a container object as the `choices` keyword argument to `add_argument()`. When the command line is parsed, argument values will be checked, and an error message will be displayed if the argument was not one of the acceptable values:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', choices='abc')
>>> parser.parse_args('c'.split())
Namespace(foo='c')
>>> parser.parse_args('X'.split())
usage: PROG [-h] {a,b,c}
PROG: error: argument foo: invalid choice: 'X' (choose from 'a', 'b', 'c')
```

Note that inclusion in the choices container is checked after any `type` conversions have been performed, so the type of the objects in the choices container should match the `type` specified:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=complex, choices=[1, 1j])
>>> parser.parse_args('1j'.split())
Namespace(foo=1j)
>>> parser.parse_args('-- -4'.split())
usage: PROG [-h] {1,1j}
PROG: error: argument foo: invalid choice: (-4+0j) (choose from 1, 1j)
```

Any object that supports the `in` operator can be passed as the choices value, so `dict` objects, `set` objects, custom containers, etc. are all supported.

## required

In general, the `argparse` module assumes that flags like `-f` and `--bar` indicate *optional* arguments, which can always be omitted at the command line. To make an option *required*, `True` can be specified for the `required=` keyword argument to `add_argument()`:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', required=True)
>>> parser.parse_args(['--foo', 'BAR'])
Namespace(foo='BAR')
>>> parser.parse_args([])
usage: argparse.py [-h] [--foo FOO]
argparse.py: error: option --foo is required
```

As the example shows, if an option is marked as required, `parse_args()` will report an error if that option is not present at the command line.

---

**Note:** Required options are generally considered bad form because users expect *options* to be *optional*, and thus they should be avoided when possible.

---

## help

The help value is a string containing a brief description of the argument. When a user requests help (usually by using `-h` or `--help` at the command line), these help descriptions will be displayed with each argument:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('--foo', action='store_true',
...     help='foo the bars before frobbling')
>>> parser.add_argument('bar', nargs='+',
...     help='one of the bars to be frobbled')
>>> parser.parse_args('-h'.split())
usage: frobble [-h] [--foo] bar [bar ...]
```

```
positional arguments:
  bar      one of the bars to be frobbled
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo      foo the bars before frobbling
```

The help strings can include various format specifiers to avoid repetition of things like the program name or the argument default. The available specifiers include the program name, `%(prog)s` and most keyword arguments to `add_argument()`, e.g. `%(default)s`, `%(type)s`, etc.:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('bar', nargs='?', type=int, default=42,
...                    help='the bar to %(prog)s (default: %(default)s)')
>>> parser.print_help()
usage: frobble [-h] [bar]
```

```
positional arguments:
  bar      the bar to frobble (default: 42)
```

```
optional arguments:
  -h, --help  show this help message and exit
```

`argparse` supports silencing the help entry for certain options, by setting the help value to `argparse.SUPPRESS`:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('--foo', help=argparse.SUPPRESS)
>>> parser.print_help()
usage: frobble [-h]
```

```
optional arguments:
  -h, --help  show this help message and exit
```

### metavar

When `ArgumentParser` generates help messages, it needs some way to refer to each expected argument. By default, `ArgumentParser` objects use the `dest` value as the “name” of each object. By default, for positional argument actions, the `dest` value is used directly, and for optional argument actions, the `dest` value is uppercased. So, a single positional argument with `dest='bar'` will be referred to as `bar`. A single optional argument `--foo` that should be followed by a single command-line argument will be referred to as `FOO`. An example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage: [-h] [--foo FOO] bar
```

```
positional arguments:
  bar
```

```
optional arguments:
```

```
-h, --help show this help message and exit
--foo FOO
```

An alternative name can be specified with `metavar`:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', metavar='YYY')
>>> parser.add_argument('bar', metavar='XXX')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage: [-h] [--foo YYY] XXX
```

```
positional arguments:
  XXX
```

```
optional arguments:
  -h, --help show this help message and exit
  --foo YYY
```

Note that `metavar` only changes the *displayed* name - the name of the attribute on the `parse_args()` object is still determined by the `dest` value.

Different values of `nargs` may cause the `metavar` to be used multiple times. Providing a tuple to `metavar` specifies a different display for each of the arguments:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', nargs=2)
>>> parser.add_argument('--foo', nargs=2, metavar=('bar', 'baz'))
>>> parser.print_help()
usage: PROG [-h] [-x X X] [--foo bar baz]
```

```
optional arguments:
  -h, --help show this help message and exit
  -x X X
  --foo bar baz
```

## dest

Most `ArgumentParser` actions add some value as an attribute of the object returned by `parse_args()`. The name of this attribute is determined by the `dest` keyword argument of `add_argument()`. For positional argument actions, `dest` is normally supplied as the first argument to `add_argument()`:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar')
>>> parser.parse_args('XXX'.split())
Namespace(bar='XXX')
```

For optional argument actions, the value of `dest` is normally inferred from the option strings. `ArgumentParser` generates the value of `dest` by taking the first long option string and stripping away the initial `--` string. If no long option strings were supplied, `dest` will be derived from the first short option string by stripping the initial `-` character. Any internal `-` characters will be converted to `_` characters to make sure the string is a valid attribute name. The examples below illustrate this behavior:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('-f', '--foo-bar', '--foo')
>>> parser.add_argument('-x', '-y')
```

```
>>> parser.parse_args('-f 1 -x 2'.split())
Namespace(foo_bar='1', x='2')
>>> parser.parse_args('--foo 1 -y 2'.split())
Namespace(foo_bar='1', x='2')
```

`dest` allows a custom attribute name to be provided:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', dest='bar')
>>> parser.parse_args('--foo XXX'.split())
Namespace(bar='XXX')
```

### 15.4.4 The `parse_args()` method

`ArgumentParser.parse_args(args=None, namespace=None)`

Convert argument strings to objects and assign them as attributes of the namespace. Return the populated namespace.

Previous calls to `add_argument()` determine exactly what objects are created and how they are assigned. See the documentation for `add_argument()` for details.

By default, the argument strings are taken from `sys.argv`, and a new empty `Namespace` object is created for the attributes.

#### Option value syntax

The `parse_args()` method supports several ways of specifying the value of an option (if it takes one). In the simplest case, the option and its value are passed as two separate arguments:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('--foo')
>>> parser.parse_args('-x X'.split())
Namespace(foo=None, x='X')
>>> parser.parse_args('--foo FOO'.split())
Namespace(foo='FOO', x=None)
```

For long options (options with names longer than a single character), the option and value can also be passed as a single command-line argument, using `=` to separate them:

```
>>> parser.parse_args('--foo=FOO'.split())
Namespace(foo='FOO', x=None)
```

For short options (options only one character long), the option and its value can be concatenated:

```
>>> parser.parse_args('-xX'.split())
Namespace(foo=None, x='X')
```

Several short options can be joined together, using only a single `-` prefix, as long as only the last option (or none of them) requires a value:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', action='store_true')
>>> parser.add_argument('-y', action='store_true')
>>> parser.add_argument('-z')
>>> parser.parse_args('-xyzZ'.split())
Namespace(x=True, y=True, z='Z')
```

## Invalid arguments

While parsing the command line, `parse_args()` checks for a variety of errors, including ambiguous options, invalid types, invalid options, wrong number of positional arguments, etc. When it encounters such an error, it exits and prints the error along with a usage message:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', type=int)
>>> parser.add_argument('bar', nargs='?')

>>> # invalid type
>>> parser.parse_args(['--foo', 'spam'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: argument --foo: invalid int value: 'spam'

>>> # invalid option
>>> parser.parse_args(['--bar'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: no such option: --bar

>>> # wrong number of arguments
>>> parser.parse_args(['spam', 'badger'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: extra arguments found: badger
```

## Arguments containing -

The `parse_args()` method attempts to give errors whenever the user has clearly made a mistake, but some situations are inherently ambiguous. For example, the command-line argument `-1` could either be an attempt to specify an option or an attempt to provide a positional argument. The `parse_args()` method is cautious here: positional arguments may only begin with `-` if they look like negative numbers and there are no options in the parser that look like negative numbers:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('foo', nargs='?')

>>> # no negative number options, so -1 is a positional argument
>>> parser.parse_args(['-x', '-1'])
Namespace(foo=None, x='-1')

>>> # no negative number options, so -1 and -5 are positional arguments
>>> parser.parse_args(['-x', '-1', '-5'])
Namespace(foo='-5', x='-1')

>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-1', dest='one')
>>> parser.add_argument('foo', nargs='?')

>>> # negative number options present, so -1 is an option
>>> parser.parse_args(['-1', 'X'])
Namespace(foo=None, one='X')

>>> # negative number options present, so -2 is an option
```

```
>>> parser.parse_args(['-2'])
usage: PROG [-h] [-1 ONE] [foo]
PROG: error: no such option: -2

>>> # negative number options present, so both -1s are options
>>> parser.parse_args(['-1', '-1'])
usage: PROG [-h] [-1 ONE] [foo]
PROG: error: argument -1: expected one argument
```

If you have positional arguments that must begin with `-` and don't look like negative numbers, you can insert the pseudo-argument `--` which tells `parse_args()` that everything after that is a positional argument:

```
>>> parser.parse_args(['--', '-f'])
Namespace(foo='-f', one=None)
```

### Argument abbreviations

The `parse_args()` method allows long options to be abbreviated if the abbreviation is unambiguous:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-bacon')
>>> parser.add_argument('-badger')
>>> parser.parse_args('-bac MMM'.split())
Namespace(bacon='MMM', badger=None)
>>> parser.parse_args('-bad WOOD'.split())
Namespace(bacon=None, badger='WOOD')
>>> parser.parse_args('-ba BA'.split())
usage: PROG [-h] [-bacon BACON] [-badger BADGER]
PROG: error: ambiguous option: -ba could match -badger, -bacon
```

An error is produced for arguments that could produce more than one options.

### Beyond `sys.argv`

Sometimes it may be useful to have an `ArgumentParser` parse arguments other than those of `sys.argv`. This can be accomplished by passing a list of strings to `parse_args()`. This is useful for testing at the interactive prompt:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument(
...     'integers', metavar='int', type=int, choices=xrange(10),
...     nargs='+', help='an integer in the range 0..9')
>>> parser.add_argument(
...     '--sum', dest='accumulate', action='store_const', const=sum,
...     default=max, help='sum the integers (default: find the max)')
>>> parser.parse_args(['1', '2', '3', '4'])
Namespace(accumulate=<built-in function max>, integers=[1, 2, 3, 4])
>>> parser.parse_args('1 2 3 4 --sum'.split())
Namespace(accumulate=<built-in function sum>, integers=[1, 2, 3, 4])
```

### The Namespace object

#### **class** `argparse.Namespace`

Simple class used by default by `parse_args()` to create an object holding attributes and return it.

This class is deliberately simple, just an `object` subclass with a readable string representation. If you prefer to have dict-like view of the attributes, you can use the standard Python idiom, `vars()`:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> args = parser.parse_args(['--foo', 'BAR'])
>>> vars(args)
{'foo': 'BAR'}
```

It may also be useful to have an `ArgumentParser` assign attributes to an already existing object, rather than a new `Namespace` object. This can be achieved by specifying the `namespace=` keyword argument:

```
>>> class C(object):
...     pass
...
>>> c = C()
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.parse_args(args=['--foo', 'BAR'], namespace=c)
>>> c.foo
'BAR'
```

## 15.4.5 Other utilities

### Sub-commands

`ArgumentParser.add_subparsers()`

Many programs split up their functionality into a number of sub-commands, for example, the `svn` program can invoke sub-commands like `svn checkout`, `svn update`, and `svn commit`. Splitting up functionality this way can be a particularly good idea when a program performs several different functions which require different kinds of command-line arguments. `ArgumentParser` supports the creation of such sub-commands with the `add_subparsers()` method. The `add_subparsers()` method is normally called with no arguments and returns a special action object. This object has a single method, `add_parser()`, which takes a command name and any `ArgumentParser` constructor arguments, and returns an `ArgumentParser` object that can be modified as usual.

Some example usage:

```
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', action='store_true', help='foo help')
>>> subparsers = parser.add_subparsers(help='sub-command help')
>>>
>>> # create the parser for the "a" command
>>> parser_a = subparsers.add_parser('a', help='a help')
>>> parser_a.add_argument('bar', type=int, help='bar help')
>>>
>>> # create the parser for the "b" command
>>> parser_b = subparsers.add_parser('b', help='b help')
>>> parser_b.add_argument('--baz', choices='XYZ', help='baz help')
>>>
>>> # parse some argument lists
>>> parser.parse_args(['a', '12'])
Namespace(bar=12, foo=False)
```

```
>>> parser.parse_args(['--foo', 'b', '--baz', 'Z'])
Namespace(baz='Z', foo=True)
```

Note that the object returned by `parse_args()` will only contain attributes for the main parser and the subparser that was selected by the command line (and not any other subparsers). So in the example above, when the `a` command is specified, only the `foo` and `bar` attributes are present, and when the `b` command is specified, only the `foo` and `baz` attributes are present.

Similarly, when a help message is requested from a subparser, only the help for that particular parser will be printed. The help message will not include parent parser or sibling parser messages. (A help message for each subparser command, however, can be given by supplying the `help=` argument to `add_parser()` as above.)

```
>>> parser.parse_args(['--help'])
usage: PROG [-h] [--foo] {a,b} ...
```

```
positional arguments:
  {a,b}  sub-command help
a       a help
b       b help
```

```
optional arguments:
  -h, --help  show this help message and exit
  --foo      foo help
```

```
>>> parser.parse_args(['a', '--help'])
usage: PROG a [-h] bar
```

```
positional arguments:
  bar      bar help
```

```
optional arguments:
  -h, --help  show this help message and exit
```

```
>>> parser.parse_args(['b', '--help'])
usage: PROG b [-h] [--baz {X,Y,Z}]
```

```
optional arguments:
  -h, --help      show this help message and exit
  --baz {X,Y,Z}  baz help
```

The `add_subparsers()` method also supports `title` and `description` keyword arguments. When either is present, the subparser's commands will appear in their own group in the help output. For example:

```
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers(title='subcommands',
...                                  description='valid subcommands',
...                                  help='additional help')
>>> subparsers.add_parser('foo')
>>> subparsers.add_parser('bar')
>>> parser.parse_args(['-h'])
usage: [-h] {foo,bar} ...
```

```
optional arguments:
  -h, --help  show this help message and exit
```

```

subcommands:
    valid subcommands

    {foo,bar}    additional help

```

One particularly effective way of handling sub-commands is to combine the use of the `add_subparsers()` method with calls to `set_defaults()` so that each subparser knows which Python function it should execute. For example:

```

>>> # sub-command functions
>>> def foo(args):
...     print args.x * args.y
...
>>> def bar(args):
...     print '(%s)' % args.z
...
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers()
>>>
>>> # create the parser for the "foo" command
>>> parser_foo = subparsers.add_parser('foo')
>>> parser_foo.add_argument('-x', type=int, default=1)
>>> parser_foo.add_argument('y', type=float)
>>> parser_foo.set_defaults(func=foo)
>>>
>>> # create the parser for the "bar" command
>>> parser_bar = subparsers.add_parser('bar')
>>> parser_bar.add_argument('z')
>>> parser_bar.set_defaults(func=bar)
>>>
>>> # parse the args and call whatever function was selected
>>> args = parser.parse_args('foo 1 -x 2'.split())
>>> args.func(args)
2.0
>>>
>>> # parse the args and call whatever function was selected
>>> args = parser.parse_args('bar XYZYX'.split())
>>> args.func(args)
((XYZYX))

```

This way, you can let `parse_args()` do the job of calling the appropriate function after argument parsing is complete. Associating functions with actions like this is typically the easiest way to handle the different actions for each of your subparsers. However, if it is necessary to check the name of the subparser that was invoked, the `dest` keyword argument to the `add_subparsers()` call will work:

```

>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers(dest='subparser_name')
>>> subparser1 = subparsers.add_parser('1')
>>> subparser1.add_argument('-x')
>>> subparser2 = subparsers.add_parser('2')
>>> subparser2.add_argument('y')

```

```
>>> parser.parse_args(['2', 'frobble'])
Namespace(subparser_name='2', y='frobble')
```

## FileType objects

**class** `argparse.FileType` (*mode='r', bufsize=None*)

The `FileType` factory creates objects that can be passed to the `type` argument of `ArgumentParser.add_argument()`. Arguments that have `FileType` objects as their type will open command-line arguments as files with the requested modes and buffer sizes:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--output', type=argparse.FileType('wb', 0))
>>> parser.parse_args(['--output', 'out'])
Namespace(output=<open file 'out', mode 'wb' at 0x...>)
```

`FileType` objects understand the pseudo-argument `'-'` and automatically convert this into `sys.stdin` for readable `FileType` objects and `sys.stdout` for writable `FileType` objects:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('infile', type=argparse.FileType('r'))
>>> parser.parse_args(['-'])
Namespace(infile=<open file '<stdin>', mode 'r' at 0x...>)
```

## Argument groups

`ArgumentParser.add_argument_group` (*title=None, description=None*)

By default, `ArgumentParser` groups command-line arguments into “positional arguments” and “optional arguments” when displaying help messages. When there is a better conceptual grouping of arguments than this default one, appropriate groups can be created using the `add_argument_group()` method:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> group = parser.add_argument_group('group')
>>> group.add_argument('--foo', help='foo help')
>>> group.add_argument('bar', help='bar help')
>>> parser.print_help()
usage: PROG [--foo FOO] bar

group:
  bar    bar help
  --foo FOO  foo help
```

The `add_argument_group()` method returns an argument group object which has an `add_argument()` method just like a regular `ArgumentParser`. When an argument is added to the group, the parser treats it just like a normal argument, but displays the argument in a separate group for help messages. The `add_argument_group()` method accepts *title* and *description* arguments which can be used to customize this display:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> group1 = parser.add_argument_group('group1', 'group1 description')
>>> group1.add_argument('foo', help='foo help')
>>> group2 = parser.add_argument_group('group2', 'group2 description')
>>> group2.add_argument('--bar', help='bar help')
>>> parser.print_help()
```

```
usage: PROG [--bar BAR] foo

group1:
  group1 description

  foo    foo help

group2:
  group2 description

  --bar BAR  bar help
```

Note that any arguments not in your user-defined groups will end up back in the usual “positional arguments” and “optional arguments” sections.

## Mutual exclusion

`argparse.add_mutually_exclusive_group` (*required=False*)

Create a mutually exclusive group. `argparse` will make sure that only one of the arguments in the mutually exclusive group was present on the command line:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group()
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args(['--foo'])
Namespace(bar=True, foo=True)
>>> parser.parse_args(['--bar'])
Namespace(bar=False, foo=False)
>>> parser.parse_args(['--foo', '--bar'])
usage: PROG [-h] [--foo | --bar]
PROG: error: argument --bar: not allowed with argument --foo
```

The `add_mutually_exclusive_group()` method also accepts a *required* argument, to indicate that at least one of the mutually exclusive arguments is required:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group(required=True)
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args([])
usage: PROG [-h] (--foo | --bar)
PROG: error: one of the arguments --foo --bar is required
```

Note that currently mutually exclusive argument groups do not support the *title* and *description* arguments of `add_argument_group()`.

## Parser defaults

`ArgumentParser.set_defaults` (*\*\*kwargs*)

Most of the time, the attributes of the object returned by `parse_args()` will be fully determined by inspecting the command-line arguments and the argument actions. `set_defaults()` allows some additional attributes that are determined without any inspection of the command line to be added:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.set_defaults(bar=42, baz='badger')
>>> parser.parse_args(['736'])
Namespace(bar=42, baz='badger', foo=736)
```

Note that parser-level defaults always override argument-level defaults:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='bar')
>>> parser.set_defaults(foo='spam')
>>> parser.parse_args([])
Namespace(foo='spam')
```

Parser-level defaults can be particularly useful when working with multiple parsers. See the `add_subparsers()` method for an example of this type.

`ArgumentParser.get_default(dest)`

Get the default value for a namespace attribute, as set by either `add_argument()` or by `set_defaults()`:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='badger')
>>> parser.get_default('foo')
'badger'
```

### Printing help

In most typical applications, `parse_args()` will take care of formatting and printing any usage or error messages. However, several formatting methods are available:

`ArgumentParser.print_usage(file=None)`

Print a brief description of how the `ArgumentParser` should be invoked on the command line. If `file` is `None`, `sys.stdout` is assumed.

`ArgumentParser.print_help(file=None)`

Print a help message, including the program usage and information about the arguments registered with the `ArgumentParser`. If `file` is `None`, `sys.stdout` is assumed.

There are also variants of these methods that simply return a string instead of printing it:

`ArgumentParser.format_usage()`

Return a string containing a brief description of how the `ArgumentParser` should be invoked on the command line.

`ArgumentParser.format_help()`

Return a string containing a help message, including the program usage and information about the arguments registered with the `ArgumentParser`.

### Partial parsing

`ArgumentParser.parse_known_args(args=None, namespace=None)`

Sometimes a script may only parse a few of the command-line arguments, passing the remaining arguments on to another script or program. In these cases, the `parse_known_args()` method can be useful. It works much like `parse_args()` except that it does not produce an error when extra arguments are present. Instead, it returns a two item tuple containing the populated namespace and the list of remaining argument strings.

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_true')
>>> parser.add_argument('bar')
>>> parser.parse_known_args(['--foo', '--badger', 'BAR', 'spam'])
(Namespace(bar='BAR', foo=True), ['--badger', 'spam'])
```

## Customizing file parsing

`ArgumentParser.convert_arg_line_to_args(arg_line)`

Arguments that are read from a file (see the `fromfile_prefix_chars` keyword argument to the `ArgumentParser` constructor) are read one argument per line. `convert_arg_line_to_args()` can be overridden for fancier reading.

This method takes a single argument `arg_line` which is a string read from the argument file. It returns a list of arguments parsed from this string. The method is called once per line read from the argument file, in order.

A useful override of this method is one that treats each space-separated word as an argument:

```
def convert_arg_line_to_args(self, arg_line):
    for arg in arg_line.split():
        if not arg.strip():
            continue
        yield arg
```

## Exiting methods

`ArgumentParser.exit(status=0, message=None)`

This method terminates the program, exiting with the specified `status` and, if given, it prints a `message` before that.

`ArgumentParser.error(message)`

This method prints a usage message including the `message` to the standard error and terminates the program with a status code of 2.

## 15.4.6 Upgrading optparse code

Originally, the `argparse` module had attempted to maintain compatibility with `optparse`. However, `optparse` was difficult to extend transparently, particularly with the changes required to support the new `kwargs=` specifiers and better usage messages. When most everything in `optparse` had either been copy-pasted over or monkey-patched, it no longer seemed practical to try to maintain the backwards compatibility.

A partial upgrade path from `optparse` to `argparse`:

- Replace `all` `optparse.OptionParser.add_option()` calls with `ArgumentParser.add_argument()` calls.
- Replace `(options, args) = parser.parse_args()` with `args = parser.parse_args()` and add additional `ArgumentParser.add_argument()` calls for the positional arguments. Keep in mind that what was previously called `options`, now in `argparse` context is called `args`.
- Replace callback actions and the `callback_*` keyword arguments with `type` or `action` arguments.
- Replace string names for `type` keyword arguments with the corresponding type objects (e.g. `int`, `float`, `complex`, etc).

- Replace `optparse.Values` with `Namespace` and `optparse.OptionError` and `optparse.OptionValueError` with `ArgumentError`.
- Replace strings with implicit arguments such as `%default` or `%prog` with the standard Python syntax to use dictionaries to format strings, that is, `%(default)s` and `%(prog)s`.
- Replace the `OptionParser` constructor version argument with a call to `parser.add_argument('--version', action='version', version='<the version>')`

## 15.5 optparse — Parser for command line options

New in version 2.3. Deprecated since version 2.7: The `optparse` module is deprecated and will not be developed further; development will continue with the `argparse` module. **Source code:** [Lib/optparse.py](#)

---

`optparse` is a more convenient, flexible, and powerful library for parsing command-line options than the old `getopt` module. `optparse` uses a more declarative style of command-line parsing: you create an instance of `OptionParser`, populate it with options, and parse the command line. `optparse` allows users to specify options in the conventional GNU/POSIX syntax, and additionally generates usage and help messages for you.

Here's an example of using `optparse` in a simple script:

```
from optparse import OptionParser
[...]
```

```
parser = OptionParser()
parser.add_option("-f", "--file", dest="filename",
                  help="write report to FILE", metavar="FILE")
parser.add_option("-q", "--quiet",
                  action="store_false", dest="verbose", default=True,
                  help="don't print status messages to stdout")

(options, args) = parser.parse_args()
```

With these few lines of code, users of your script can now do the “usual thing” on the command-line, for example:

```
<yourscript> --file=outfile -q
```

As it parses the command line, `optparse` sets attributes of the options object returned by `parse_args()` based on user-supplied command-line values. When `parse_args()` returns from parsing this command line, `options.filename` will be `"outfile"` and `options.verbose` will be `False`. `optparse` supports both long and short options, allows short options to be merged together, and allows options to be associated with their arguments in a variety of ways. Thus, the following command lines are all equivalent to the above example:

```
<yourscript> -f outfile --quiet
<yourscript> --quiet --file outfile
<yourscript> -q -foutfile
<yourscript> -qfoutfile
```

Additionally, users can run one of

```
<yourscript> -h
<yourscript> --help
```

and `optparse` will print out a brief summary of your script's options:

```
Usage: <yourscript> [options]
```

Options:

```
-h, --help          show this help message and exit
-f FILE, --file=FILE write report to FILE
-q, --quiet         don't print status messages to stdout
```

where the value of *yourscript* is determined at runtime (normally from `sys.argv[0]`).

## 15.5.1 Background

`optparse` was explicitly designed to encourage the creation of programs with straightforward, conventional command-line interfaces. To that end, it supports only the most common command-line syntax and semantics conventionally used under Unix. If you are unfamiliar with these conventions, read this section to acquaint yourself with them.

### Terminology

**argument** a string entered on the command-line, and passed by the shell to `execl()` or `execv()`. In Python, arguments are elements of `sys.argv[1:]` (`sys.argv[0]` is the name of the program being executed). Unix shells also use the term “word”.

It is occasionally desirable to substitute an argument list other than `sys.argv[1:]`, so you should read “argument” as “an element of `sys.argv[1:]`, or of some other list provided as a substitute for `sys.argv[1:]`”.

**option** an argument used to supply extra information to guide or customize the execution of a program. There are many different syntaxes for options; the traditional Unix syntax is a hyphen (“-”) followed by a single letter, e.g. `-x` or `-F`. Also, traditional Unix syntax allows multiple options to be merged into a single argument, e.g. `-x -F` is equivalent to `-xF`. The GNU project introduced `--` followed by a series of hyphen-separated words, e.g. `--file` or `--dry-run`. These are the only two option syntaxes provided by `optparse`.

Some other option syntaxes that the world has seen include:

- a hyphen followed by a few letters, e.g. `-pf` (this is *not* the same as multiple options merged into a single argument)
- a hyphen followed by a whole word, e.g. `-file` (this is technically equivalent to the previous syntax, but they aren’t usually seen in the same program)
- a plus sign followed by a single letter, or a few letters, or a word, e.g. `+f`, `+rgb`
- a slash followed by a letter, or a few letters, or a word, e.g. `/f`, `/file`

These option syntaxes are not supported by `optparse`, and they never will be. This is deliberate: the first three are non-standard on any environment, and the last only makes sense if you’re exclusively targeting VMS, MS-DOS, and/or Windows.

**option argument** an argument that follows an option, is closely associated with that option, and is consumed from the argument list when that option is. With `optparse`, option arguments may either be in a separate argument from their option:

```
-f foo
--file foo
```

or included in the same argument:

```
-ffoo
--file=foo
```

Typically, a given option either takes an argument or it doesn’t. Lots of people want an “optional option arguments” feature, meaning that some options will take an argument if they see it, and won’t if they don’t. This

is somewhat controversial, because it makes parsing ambiguous: if `-a` takes an optional argument and `-b` is another option entirely, how do we interpret `-ab`? Because of this ambiguity, `optparse` does not support this feature.

**positional argument** something leftover in the argument list after options have been parsed, i.e. after options and their arguments have been parsed and removed from the argument list.

**required option** an option that must be supplied on the command-line; note that the phrase “required option” is self-contradictory in English. `optparse` doesn’t prevent you from implementing required options, but doesn’t give you much help at it either.

For example, consider this hypothetical command-line:

```
prog -v --report /tmp/report.txt foo bar
```

`-v` and `--report` are both options. Assuming that `--report` takes one argument, `/tmp/report.txt` is an option argument. `foo` and `bar` are positional arguments.

### What are options for?

Options are used to provide extra information to tune or customize the execution of a program. In case it wasn’t clear, options are usually *optional*. A program should be able to run just fine with no options whatsoever. (Pick a random program from the Unix or GNU toolsets. Can it run without any options at all and still make sense? The main exceptions are `find`, `tar`, and `dd`—all of which are mutant oddballs that have been rightly criticized for their non-standard syntax and confusing interfaces.)

Lots of people want their programs to have “required options”. Think about it. If it’s required, then it’s *not optional*! If there is a piece of information that your program absolutely requires in order to run successfully, that’s what positional arguments are for.

As an example of good command-line interface design, consider the humble `cp` utility, for copying files. It doesn’t make much sense to try to copy files without supplying a destination and at least one source. Hence, `cp` fails if you run it with no arguments. However, it has a flexible, useful syntax that does not require any options at all:

```
cp SOURCE DEST
cp SOURCE ... DEST-DIR
```

You can get pretty far with just that. Most `cp` implementations provide a bunch of options to tweak exactly how the files are copied: you can preserve mode and modification time, avoid following symlinks, ask before clobbering existing files, etc. But none of this distracts from the core mission of `cp`, which is to copy either one file to another, or several files to another directory.

### What are positional arguments for?

Positional arguments are for those pieces of information that your program absolutely, positively requires to run.

A good user interface should have as few absolute requirements as possible. If your program requires 17 distinct pieces of information in order to run successfully, it doesn’t much matter *how* you get that information from the user—most people will give up and walk away before they successfully run the program. This applies whether the user interface is a command-line, a configuration file, or a GUI: if you make that many demands on your users, most of them will simply give up.

In short, try to minimize the amount of information that users are absolutely required to supply—use sensible defaults whenever possible. Of course, you also want to make your programs reasonably flexible. That’s what options are for. Again, it doesn’t matter if they are entries in a config file, widgets in the “Preferences” dialog of a GUI, or command-line options—the more options you implement, the more flexible your program is, and the more complicated its implementation becomes. Too much flexibility has drawbacks as well, of course; too many options can overwhelm users and make your code much harder to maintain.

## 15.5.2 Tutorial

While `optparse` is quite flexible and powerful, it's also straightforward to use in most cases. This section covers the code patterns that are common to any `optparse`-based program.

First, you need to import the `OptionParser` class; then, early in the main program, create an `OptionParser` instance:

```
from optparse import OptionParser
[...]
```

```
parser = OptionParser()
```

Then you can start defining options. The basic syntax is:

```
parser.add_option(opt_str, ...,
                  attr=value, ...)
```

Each option has one or more option strings, such as `-f` or `--file`, and several option attributes that tell `optparse` what to expect and what to do when it encounters that option on the command line.

Typically, each option will have one short option string and one long option string, e.g.:

```
parser.add_option("-f", "--file", ...)
```

You're free to define as many short option strings and as many long option strings as you like (including zero), as long as there is at least one option string overall.

The option strings passed to `OptionParser.add_option()` are effectively labels for the option defined by that call. For brevity, we will frequently refer to *encountering an option* on the command line; in reality, `optparse` encounters *option strings* and looks up options from them.

Once all of your options are defined, instruct `optparse` to parse your program's command line:

```
(options, args) = parser.parse_args()
```

(If you like, you can pass a custom argument list to `parse_args()`, but that's rarely necessary: by default it uses `sys.argv[1:]`.)

`parse_args()` returns two values:

- `options`, an object containing values for all of your options—e.g. if `--file` takes a single string argument, then `options.file` will be the filename supplied by the user, or `None` if the user did not supply that option
- `args`, the list of positional arguments leftover after parsing options

This tutorial section only covers the four most important option attributes: `action`, `type`, `dest` (destination), and `help`. Of these, `action` is the most fundamental.

### Understanding option actions

Actions tell `optparse` what to do when it encounters an option on the command line. There is a fixed set of actions hard-coded into `optparse`; adding new actions is an advanced topic covered in section *Extending optparse*. Most actions tell `optparse` to store a value in some variable—for example, take a string from the command line and store it in an attribute of `options`.

If you don't specify an option action, `optparse` defaults to `store`.

### The store action

The most common option action is `store`, which tells `optparse` to take the next argument (or the remainder of the current argument), ensure that it is of the correct type, and store it to your chosen destination.

For example:

```
parser.add_option("-f", "--file",
                  action="store", type="string", dest="filename")
```

Now let's make up a fake command line and ask `optparse` to parse it:

```
args = ["-f", "foo.txt"]
(options, args) = parser.parse_args(args)
```

When `optparse` sees the option string `-f`, it consumes the next argument, `foo.txt`, and stores it in `options.filename`. So, after this call to `parse_args()`, `options.filename` is `"foo.txt"`.

Some other option types supported by `optparse` are `int` and `float`. Here's an option that expects an integer argument:

```
parser.add_option("-n", type="int", dest="num")
```

Note that this option has no long option string, which is perfectly acceptable. Also, there's no explicit action, since the default is `store`.

Let's parse another fake command-line. This time, we'll jam the option argument right up against the option: since `-n42` (one argument) is equivalent to `-n 42` (two arguments), the code

```
(options, args) = parser.parse_args(["-n42"])
print options.num
```

will print `42`.

If you don't specify a type, `optparse` assumes `string`. Combined with the fact that the default action is `store`, that means our first example can be a lot shorter:

```
parser.add_option("-f", "--file", dest="filename")
```

If you don't supply a destination, `optparse` figures out a sensible default from the option strings: if the first long option string is `--foo-bar`, then the default destination is `foo_bar`. If there are no long option strings, `optparse` looks at the first short option string: the default destination for `-f` is `f`.

`optparse` also includes built-in `long` and `complex` types. Adding types is covered in section [Extending optparse](#).

### Handling boolean (flag) options

Flag options—set a variable to `true` or `false` when a particular option is seen—are quite common. `optparse` supports them with two separate actions, `store_true` and `store_false`. For example, you might have a `verbose` flag that is turned on with `-v` and off with `-q`:

```
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose")
```

Here we have two different options with the same destination, which is perfectly OK. (It just means you have to be a bit careful when setting default values—see below.)

When `optparse` encounters `-v` on the command line, it sets `options.verbose` to `True`; when it encounters `-q`, `options.verbose` is set to `False`.

### Other actions

Some other actions supported by `optparse` are:

- `"store_const"` store a constant value
- `"append"` append this option's argument to a list
- `"count"` increment a counter by one

"callback" call a specified function

These are covered in section *Reference Guide*, Reference Guide and section *Option Callbacks*.

## Default values

All of the above examples involve setting some variable (the “destination”) when certain command-line options are seen. What happens if those options are never seen? Since we didn’t supply any defaults, they are all set to None. This is usually fine, but sometimes you want more control. `optparse` lets you supply a default value for each destination, which is assigned before the command line is parsed.

First, consider the verbose/quiet example. If we want `optparse` to set `verbose` to `True` unless `-q` is seen, then we can do this:

```
parser.add_option("-v", action="store_true", dest="verbose", default=True)
parser.add_option("-q", action="store_false", dest="verbose")
```

Since default values apply to the *destination* rather than to any particular option, and these two options happen to have the same destination, this is exactly equivalent:

```
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose", default=True)
```

Consider this:

```
parser.add_option("-v", action="store_true", dest="verbose", default=False)
parser.add_option("-q", action="store_false", dest="verbose", default=True)
```

Again, the default value for `verbose` will be `True`: the last default value supplied for any particular destination is the one that counts.

A clearer way to specify default values is the `set_defaults()` method of `OptionParser`, which you can call at any time before calling `parse_args()`:

```
parser.set_defaults(verbose=True)
parser.add_option(...)
(options, args) = parser.parse_args()
```

As before, the last value specified for a given option destination is the one that counts. For clarity, try to use one method or the other of setting default values, not both.

## Generating help

`optparse`’s ability to generate help and usage text automatically is useful for creating user-friendly command-line interfaces. All you have to do is supply a `help` value for each option, and optionally a short usage message for your whole program. Here’s an `OptionParser` populated with user-friendly (documented) options:

```
usage = "usage: %prog [options] arg1 arg2"
parser = OptionParser(usage=usage)
parser.add_option("-v", "--verbose",
                  action="store_true", dest="verbose", default=True,
                  help="make lots of noise [default]")
parser.add_option("-q", "--quiet",
                  action="store_false", dest="verbose",
                  help="be vewwy quiet (I'm hunting wabbits)")
parser.add_option("-f", "--filename",
                  metavar="FILE", help="write output to FILE")
parser.add_option("-m", "--mode",
                  default="intermediate",
```

```
help="interaction mode: novice, intermediate, "  
      "or expert [default: %default]")
```

If `optparse` encounters either `-h` or `--help` on the command-line, or if you just call `parser.print_help()`, it prints the following to standard output:

```
Usage: <yourscript> [options] arg1 arg2
```

Options:

```
-h, --help          show this help message and exit  
-v, --verbose      make lots of noise [default]  
-q, --quiet        be vewwy quiet (I'm hunting wabbits)  
-f FILE, --filename=FILE  
                   write output to FILE  
-m MODE, --mode=MODE interaction mode: novice, intermediate, or  
                   expert [default: intermediate]
```

(If the help output is triggered by a help option, `optparse` exits after printing the help text.)

There's a lot going on here to help `optparse` generate the best possible help message:

- the script defines its own usage message:

```
usage = "usage: %prog [options] arg1 arg2"
```

`optparse` expands `%prog` in the usage string to the name of the current program, i.e. `os.path.basename(sys.argv[0])`. The expanded string is then printed before the detailed option help.

If you don't supply a usage string, `optparse` uses a bland but sensible default: `"Usage: %prog [options]"`, which is fine if your script doesn't take any positional arguments.

- every option defines a help string, and doesn't worry about line-wrapping—`optparse` takes care of wrapping lines and making the help output look good.
- options that take a value indicate this fact in their automatically-generated help message, e.g. for the “mode” option:

```
-m MODE, --mode=MODE
```

Here, “MODE” is called the meta-variable: it stands for the argument that the user is expected to supply to `-m/--mode`. By default, `optparse` converts the destination variable name to uppercase and uses that for the meta-variable. Sometimes, that's not what you want—for example, the `--filename` option explicitly sets `metavar="FILE"`, resulting in this automatically-generated option description:

```
-f FILE, --filename=FILE
```

This is important for more than just saving space, though: the manually written help text uses the meta-variable `FILE` to clue the user in that there's a connection between the semi-formal syntax `-f FILE` and the informal semantic description “write output to `FILE`”. This is a simple but effective way to make your help text a lot clearer and more useful for end users.

New in version 2.4: Options that have a default value can include `%default` in the help string—`optparse` will replace it with `str()` of the option's default value. If an option has no default value (or the default value is `None`), `%default` expands to `none`.

### Grouping Options

When dealing with many options, it is convenient to group these options for better help output. An `OptionParser` can contain several option groups, each of which can contain several options.

An option group is obtained using the class `OptionGroup`:

```
class optparse.OptionGroup (parser, title, description=None)
    where
```

- `parser` is the `OptionParser` instance the group will be inserted in to
- `title` is the group title
- `description`, optional, is a long description of the group

`OptionGroup` inherits from `OptionContainer` (like `OptionParser`) and so the `add_option()` method can be used to add an option to the group.

Once all the options are declared, using the `OptionParser` method `add_option_group()` the group is added to the previously defined parser.

Continuing with the parser defined in the previous section, adding an `OptionGroup` to a parser is easy:

```
group = OptionGroup(parser, "Dangerous Options",
                    "Caution: use these options at your own risk. "
                    "It is believed that some of them bite.")
group.add_option("-g", action="store_true", help="Group option.")
parser.add_option_group(group)
```

This would result in the following help output:

```
Usage: <yourscript> [options] arg1 arg2
```

Options:

```
-h, --help            show this help message and exit
-v, --verbose         make lots of noise [default]
-q, --quiet           be vewwy quiet (I'm hunting wabbits)
-f FILE, --filename=FILE
                        write output to FILE
-m MODE, --mode=MODE  interaction mode: novice, intermediate, or
                        expert [default: intermediate]
```

Dangerous Options:

```
Caution: use these options at your own risk. It is believed that some
of them bite.
```

```
-g                    Group option.
```

A bit more complete example might involve using more than one group: still extending the previous example:

```
group = OptionGroup(parser, "Dangerous Options",
                    "Caution: use these options at your own risk. "
                    "It is believed that some of them bite.")
group.add_option("-g", action="store_true", help="Group option.")
parser.add_option_group(group)

group = OptionGroup(parser, "Debug Options")
group.add_option("-d", "--debug", action="store_true",
                help="Print debug information")
group.add_option("-s", "--sql", action="store_true",
                help="Print all SQL statements executed")
group.add_option("-e", action="store_true", help="Print every action done")
parser.add_option_group(group)
```

that results in the following output:

```
Usage: <yourscript> [options] arg1 arg2
```

Options:

```
-h, --help            show this help message and exit
-v, --verbose         make lots of noise [default]
-q, --quiet           be vewwy quiet (I'm hunting wabbits)
-f FILE, --filename=FILE
                        write output to FILE
-m MODE, --mode=MODE  interaction mode: novice, intermediate, or expert
                        [default: intermediate]
```

Dangerous Options:

Caution: use these options at your own risk. It is believed that some of them bite.

```
-g                    Group option.
```

Debug Options:

```
-d, --debug          Print debug information
-s, --sql            Print all SQL statements executed
-e                  Print every action done
```

Another interesting method, in particular when working programmatically with option groups is:

`OptionParser.get_option_group(opt_str)`

Return the `OptionGroup` to which the short or long option string *opt\_str* (e.g. `'-o'` or `'--option'`) belongs. If there's no such `OptionGroup`, return `None`.

### Printing a version string

Similar to the brief usage string, `optparse` can also print a version string for your program. You have to supply the string as the `version` argument to `OptionParser`:

```
parser = OptionParser(usage="%prog [-f] [-q]", version="%prog 1.0")
```

`%prog` is expanded just like it is in usage. Apart from that, `version` can contain anything you like. When you supply it, `optparse` automatically adds a `--version` option to your parser. If it encounters this option on the command line, it expands your `version` string (by replacing `%prog`), prints it to `stdout`, and exits.

For example, if your script is called `/usr/bin/foo`:

```
$ /usr/bin/foo --version
foo 1.0
```

The following two methods can be used to print and get the `version` string:

`OptionParser.print_version(file=None)`

Print the version message for the current program (`self.version`) to *file* (default `stdout`). As with `print_usage()`, any occurrence of `%prog` in `self.version` is replaced with the name of the current program. Does nothing if `self.version` is empty or undefined.

`OptionParser.get_version()`

Same as `print_version()` but returns the version string instead of printing it.

## How `optparse` handles errors

There are two broad classes of errors that `optparse` has to worry about: programmer errors and user errors. Programmer errors are usually erroneous calls to `OptionParser.add_option()`, e.g. invalid option strings, unknown option attributes, missing option attributes, etc. These are dealt with in the usual way: raise an exception (either `optparse.OptionError` or `TypeError`) and let the program crash.

Handling user errors is much more important, since they are guaranteed to happen no matter how stable your code is. `optparse` can automatically detect some user errors, such as bad option arguments (passing `-n 4x` where `-n` takes an integer argument), missing arguments (`-n` at the end of the command line, where `-n` takes an argument of any type). Also, you can call `OptionParser.error()` to signal an application-defined error condition:

```
(options, args) = parser.parse_args()
[...]
if options.a and options.b:
    parser.error("options -a and -b are mutually exclusive")
```

In either case, `optparse` handles the error the same way: it prints the program's usage message and an error message to standard error and exits with error status 2.

Consider the first example above, where the user passes `4x` to an option that takes an integer:

```
$ /usr/bin/foo -n 4x
Usage: foo [options]

foo: error: option -n: invalid integer value: '4x'
```

Or, where the user fails to pass a value at all:

```
$ /usr/bin/foo -n
Usage: foo [options]

foo: error: -n option requires an argument
```

`optparse`-generated error messages take care always to mention the option involved in the error; be sure to do the same when calling `OptionParser.error()` from your application code.

If `optparse`'s default error-handling behaviour does not suit your needs, you'll need to subclass `OptionParser` and override its `exit()` and/or `error()` methods.

## Putting it all together

Here's what `optparse`-based scripts usually look like:

```
from optparse import OptionParser
[...]
def main():
    usage = "usage: %prog [options] arg"
    parser = OptionParser(usage)
    parser.add_option("-f", "--file", dest="filename",
                    help="read data from FILENAME")
    parser.add_option("-v", "--verbose",
                    action="store_true", dest="verbose")
    parser.add_option("-q", "--quiet",
                    action="store_false", dest="verbose")
    [...]
    (options, args) = parser.parse_args()
    if len(args) != 1:
```

```
        parser.error("incorrect number of arguments")
    if options.verbose:
        print "reading %s..." % options.filename
    [...]

if __name__ == "__main__":
    main()
```

## 15.5.3 Reference Guide

### Creating the parser

The first step in using `optparse` is to create an `OptionParser` instance.

**class** `optparse.OptionParser(...)`

The `OptionParser` constructor has no required arguments, but a number of optional keyword arguments. You should always pass them as keyword arguments, i.e. do not rely on the order in which the arguments are declared.

**usage (default: "%prog [options]")** The usage summary to print when your program is run incorrectly or with a help option. When `optparse` prints the usage string, it expands `%prog` to `os.path.basename(sys.argv[0])` (or to `prog` if you passed that keyword argument). To suppress a usage message, pass the special value `optparse.SUPPRESS_USAGE`.

**option\_list (default: [])** A list of `Option` objects to populate the parser with. The options in `option_list` are added after any options in `standard_option_list` (a class attribute that may be set by `OptionParser` subclasses), but before any version or help options. Deprecated; use `add_option()` after creating the parser instead.

**option\_class (default: `optparse.Option`)** Class to use when adding options to the parser in `add_option()`.

**version (default: `None`)** A version string to print when the user supplies a version option. If you supply a true value for `version`, `optparse` automatically adds a version option with the single option string `--version`. The substring `%prog` is expanded the same as for `usage`.

**conflict\_handler (default: "error")** Specifies what to do when options with conflicting option strings are added to the parser; see section *Conflicts between options*.

**description (default: `None`)** A paragraph of text giving a brief overview of your program. `optparse` reformats this paragraph to fit the current terminal width and prints it when the user requests help (after `usage`, but before the list of options).

**formatter (default: a new `IndentedHelpFormatter`)** An instance of `optparse.HelpFormatter` that will be used for printing help text. `optparse` provides two concrete classes for this purpose: `IndentedHelpFormatter` and `TitledHelpFormatter`.

**add\_help\_option (default: `True`)** If true, `optparse` will add a help option (with option strings `-h` and `--help`) to the parser.

**prog** The string to use when expanding `%prog` in `usage` and `version` instead of `os.path.basename(sys.argv[0])`.

**epilog (default: `None`)** A paragraph of help text to print after the option help.

### Populating the parser

There are several ways to populate the parser with options. The preferred way is by using `OptionParser.add_option()`, as shown in section *Tutorial*. `add_option()` can be called in one of

two ways:

- pass it an `Option` instance (as returned by `make_option()`)
- pass it any combination of positional and keyword arguments that are acceptable to `make_option()` (i.e., to the `Option` constructor), and it will create the `Option` instance for you

The other alternative is to pass a list of pre-constructed `Option` instances to the `OptionParser` constructor, as in:

```
option_list = [
    make_option("-f", "--filename",
                action="store", type="string", dest="filename"),
    make_option("-q", "--quiet",
                action="store_false", dest="verbose"),
]
parser = OptionParser(option_list=option_list)
```

(`make_option()` is a factory function for creating `Option` instances; currently it is an alias for the `Option` constructor. A future version of `optparse` may split `Option` into several classes, and `make_option()` will pick the right class to instantiate. Do not instantiate `Option` directly.)

## Defining options

Each `Option` instance represents a set of synonymous command-line option strings, e.g. `-f` and `--file`. You can specify any number of short or long option strings, but you must specify at least one overall option string.

The canonical way to create an `Option` instance is with the `add_option()` method of `OptionParser`.

```
OptionParser.add_option(option)
OptionParser.add_option(*opt_str, attr=value, ...)
```

To define an option with only a short option string:

```
parser.add_option("-f", attr=value, ...)
```

And to define an option with only a long option string:

```
parser.add_option("--foo", attr=value, ...)
```

The keyword arguments define attributes of the new `Option` object. The most important option attribute is `action`, and it largely determines which other attributes are relevant or required. If you pass irrelevant option attributes, or fail to pass required ones, `optparse` raises an `OptionError` exception explaining your mistake.

An option's `action` determines what `optparse` does when it encounters this option on the command-line. The standard option actions hard-coded into `optparse` are:

- "**store**" store this option's argument (default)
- "**store\_const**" store a constant value
- "**store\_true**" store a true value
- "**store\_false**" store a false value
- "**append**" append this option's argument to a list
- "**append\_const**" append a constant value to a list
- "**count**" increment a counter by one
- "**callback**" call a specified function

`"help"` print a usage message including all options and the documentation for them

(If you don't supply an action, the default is `"store"`. For this action, you may also supply `type` and `dest` option attributes; see *Standard option actions*.)

As you can see, most actions involve storing or updating a value somewhere. `optparse` always creates a special object for this, conventionally called `options` (it happens to be an instance of `optparse.Values`). Option arguments (and various other values) are stored as attributes of this object, according to the `dest` (destination) option attribute.

For example, when you call

```
parser.parse_args()
```

one of the first things `optparse` does is create the `options` object:

```
options = Values()
```

If one of the options in this parser is defined with

```
parser.add_option("-f", "--file", action="store", type="string", dest="filename")
```

and the command-line being parsed includes any of the following:

```
-ffoo
-f foo
--file=foo
--file foo
```

then `optparse`, on seeing this option, will do the equivalent of

```
options.filename = "foo"
```

The `type` and `dest` option attributes are almost as important as `action`, but `action` is the only one that makes sense for *all* options.

### Option attributes

The following option attributes may be passed as keyword arguments to `OptionParser.add_option()`. If you pass an option attribute that is not relevant to a particular option, or fail to pass a required option attribute, `optparse` raises `OptionError`.

**Option.action**  
(default: `"store"`)

Determines `optparse`'s behaviour when this option is seen on the command line; the available options are documented *here*.

**Option.type**  
(default: `"string"`)

The argument type expected by this option (e.g., `"string"` or `"int"`); the available option types are documented *here*.

**Option.dest**  
(default: derived from option strings)

If the option's action implies writing or modifying a value somewhere, this tells `optparse` where to write it: `dest` names an attribute of the `options` object that `optparse` builds as it parses the command line.

**Option.default**  
The value to use for this option's destination if the option is not seen on the command line. See also `OptionParser.set_defaults()`.

`Option.nargs`  
(default: 1)

How many arguments of type `type` should be consumed when this option is seen. If  $> 1$ , `optparse` will store a tuple of values to `dest`.

`Option.const`  
For actions that store a constant value, the constant value to store.

`Option.choices`  
For options of type "choice", the list of strings the user may choose from.

`Option.callback`  
For options with action "callback", the callable to call when this option is seen. See section *Option Callbacks* for detail on the arguments passed to the callable.

`Option.callback_args`

`Option.callback_kwargs`

Additional positional and keyword arguments to pass to `callback` after the four standard callback arguments.

`Option.help`  
Help text to print for this option when listing all available options after the user supplies a `help` option (such as `--help`). If no help text is supplied, the option will be listed without help text. To hide this option, use the special value `optparse.SUPPRESS_HELP`.

`Option.metavar`  
(default: derived from option strings)

Stand-in for the option argument(s) to use when printing help text. See section *Tutorial* for an example.

## Standard option actions

The various option actions all have slightly different requirements and effects. Most actions have several relevant option attributes which you may specify to guide `optparse`'s behaviour; a few have required attributes, which you must specify for any option using that action.

- "store" [relevant: `type`, `dest`, `nargs`, `choices`]

The option must be followed by an argument, which is converted to a value according to `type` and stored in `dest`. If `nargs > 1`, multiple arguments will be consumed from the command line; all will be converted according to `type` and stored to `dest` as a tuple. See the *Standard option types* section.

If `choices` is supplied (a list or tuple of strings), the type defaults to "choice".

If `type` is not supplied, it defaults to "string".

If `dest` is not supplied, `optparse` derives a destination from the first long option string (e.g., `--foo-bar` implies `foo_bar`). If there are no long option strings, `optparse` derives a destination from the first short option string (e.g., `-f` implies `f`).

Example:

```
parser.add_option("-f")
parser.add_option("-p", type="float", nargs=3, dest="point")
```

As it parses the command line

```
-f foo.txt -p 1 -3.5 4 -fbar.txt
```

`optparse` will set

```
options.f = "foo.txt"
options.point = (1.0, -3.5, 4.0)
options.f = "bar.txt"
```

- "store\_const" [required: `const`; relevant: `dest`]

The value `const` is stored in `dest`.

Example:

```
parser.add_option("-q", "--quiet",
                  action="store_const", const=0, dest="verbose")
parser.add_option("-v", "--verbose",
                  action="store_const", const=1, dest="verbose")
parser.add_option("--noisy",
                  action="store_const", const=2, dest="verbose")
```

If `--noisy` is seen, `optparse` will set

```
options.verbose = 2
```

- "store\_true" [relevant: `dest`]

A special case of "store\_const" that stores a true value to `dest`.

- "store\_false" [relevant: `dest`]

Like "store\_true", but stores a false value.

Example:

```
parser.add_option("--clobber", action="store_true", dest="clobber")
parser.add_option("--no-clobber", action="store_false", dest="clobber")
```

- "append" [relevant: `type`, `dest`, `nargs`, `choices`]

The option must be followed by an argument, which is appended to the list in `dest`. If no default value for `dest` is supplied, an empty list is automatically created when `optparse` first encounters this option on the command-line. If `nargs > 1`, multiple arguments are consumed, and a tuple of length `nargs` is appended to `dest`.

The defaults for `type` and `dest` are the same as for the "store" action.

Example:

```
parser.add_option("-t", "--tracks", action="append", type="int")
```

If `-t3` is seen on the command-line, `optparse` does the equivalent of:

```
options.tracks = []
options.tracks.append(int("3"))
```

If, a little later on, `--tracks=4` is seen, it does:

```
options.tracks.append(int("4"))
```

The `append` action calls the `append` method on the current value of the option. This means that any default value specified must have an `append` method. It also means that if the default value is non-empty, the default elements will be present in the parsed value for the option, with any values from the command line appended after those default values:

```
>>> parser.add_option("--files", action="append", default=['~/mypkg/defaults'])
>>> opts, args = parser.parse_args(['--files', 'overrides.mypkg'])
>>> opts.files
['~/mypkg/defaults', 'overrides.mypkg']
```

- "append\_const" [required: `const`; relevant: `dest`]

Like "store\_const", but the value `const` is appended to `dest`; as with "append", `dest` defaults to `None`, and an empty list is automatically created the first time the option is encountered.

- "count" [relevant: `dest`]

Increment the integer stored at `dest`. If no default value is supplied, `dest` is set to zero before being incremented the first time.

Example:

```
parser.add_option("-v", action="count", dest="verbosity")
```

The first time `-v` is seen on the command line, `optparse` does the equivalent of:

```
options.verbosity = 0
options.verbosity += 1
```

Every subsequent occurrence of `-v` results in

```
options.verbosity += 1
```

- "callback" [required: `callback`; relevant: `type`, `nargs`, `callback_args`, `callback_kwargs`]

Call the function specified by `callback`, which is called as

```
func(option, opt_str, value, parser, *args, **kwargs)
```

See section *Option Callbacks* for more detail.

- "help"

Prints a complete help message for all the options in the current option parser. The help message is constructed from the `usage` string passed to `OptionParser`'s constructor and the `help` string passed to every option.

If no `help` string is supplied for an option, it will still be listed in the help message. To omit an option entirely, use the special value `optparse.SUPPRESS_HELP`.

`optparse` automatically adds a `help` option to all `OptionParsers`, so you do not normally need to create one.

Example:

```
from optparse import OptionParser, SUPPRESS_HELP
```

```
# usually, a help option is added automatically, but that can
# be suppressed using the add_help_option argument
parser = OptionParser(add_help_option=False)
```

```
parser.add_option("-h", "--help", action="help")
parser.add_option("-v", action="store_true", dest="verbose",
                  help="Be moderately verbose")
parser.add_option("--file", dest="filename",
                  help="Input file to read data from")
parser.add_option("--secret", help=SUPPRESS_HELP)
```

If `optparse` sees either `-h` or `--help` on the command line, it will print something like the following help message to `stdout` (assuming `sys.argv[0]` is `"foo.py"`):

```
Usage: foo.py [options]
```

Options:

```
-h, --help          Show this help message and exit
```

```
-v                Be moderately verbose
--file=FILENAME  Input file to read data from
```

After printing the help message, `optparse` terminates your process with `sys.exit(0)`.

- "version"

Prints the version number supplied to the `OptionParser` to stdout and exits. The version number is actually formatted and printed by the `print_version()` method of `OptionParser`. Generally only relevant if the `version` argument is supplied to the `OptionParser` constructor. As with `help` options, you will rarely create `version` options, since `optparse` automatically adds them when needed.

### Standard option types

`optparse` has six built-in option types: "string", "int", "long", "choice", "float" and "complex". If you need to add new option types, see section *Extending optparse*.

Arguments to string options are not checked or converted in any way: the text on the command line is stored in the destination (or passed to the callback) as-is.

Integer arguments (type "int" or "long") are parsed as follows:

- if the number starts with `0x`, it is parsed as a hexadecimal number
- if the number starts with `0`, it is parsed as an octal number
- if the number starts with `0b`, it is parsed as a binary number
- otherwise, the number is parsed as a decimal number

The conversion is done by calling either `int()` or `long()` with the appropriate base (2, 8, 10, or 16). If this fails, so will `optparse`, although with a more useful error message.

"float" and "complex" option arguments are converted directly with `float()` and `complex()`, with similar error-handling.

"choice" options are a subtype of "string" options. The `choices` option attribute (a sequence of strings) defines the set of allowed option arguments. `optparse.check_choice()` compares user-supplied option arguments against this master list and raises `OptionValueError` if an invalid string is given.

### Parsing arguments

The whole point of creating and populating an `OptionParser` is to call its `parse_args()` method:

```
(options, args) = parser.parse_args(args=None, values=None)
```

where the input parameters are

**args** the list of arguments to process (default: `sys.argv[1:]`)

**values** a `optparse.Values` object to store option arguments in (default: a new instance of `Values`) – if you give an existing object, the option defaults will not be initialized on it

and the return values are

**options** the same object that was passed in as `values`, or the `optparse.Values` instance created by `optparse`

**args** the leftover positional arguments after all options have been processed

The most common usage is to supply neither keyword argument. If you supply `values`, it will be modified with repeated `setattr()` calls (roughly one for every option argument stored to an option destination) and returned by `parse_args()`.

If `parse_args()` encounters any errors in the argument list, it calls the `OptionParser`'s `error()` method with an appropriate end-user error message. This ultimately terminates your process with an exit status of 2 (the traditional Unix exit status for command-line errors).

## Querying and manipulating your option parser

The default behavior of the option parser can be customized slightly, and you can also poke around your option parser and see what's there. `OptionParser` provides several methods to help you out:

`OptionParser.disable_interspersed_args()`

Set parsing to stop on the first non-option. For example, if `-a` and `-b` are both simple options that take no arguments, `optparse` normally accepts this syntax:

```
prog -a arg1 -b arg2
```

and treats it as equivalent to

```
prog -a -b arg1 arg2
```

To disable this feature, call `disable_interspersed_args()`. This restores traditional Unix syntax, where option parsing stops with the first non-option argument.

Use this if you have a command processor which runs another command which has options of its own and you want to make sure these options don't get confused. For example, each command might have a different set of options.

`OptionParser.enable_interspersed_args()`

Set parsing to not stop on the first non-option, allowing interspersing switches with command arguments. This is the default behavior.

`OptionParser.get_option(opt_str)`

Returns the `Option` instance with the option string `opt_str`, or `None` if no options have that option string.

`OptionParser.has_option(opt_str)`

Return true if the `OptionParser` has an option with option string `opt_str` (e.g., `-q` or `--verbose`).

`OptionParser.remove_option(opt_str)`

If the `OptionParser` has an option corresponding to `opt_str`, that option is removed. If that option provided any other option strings, all of those option strings become invalid. If `opt_str` does not occur in any option belonging to this `OptionParser`, raises `ValueError`.

## Conflicts between options

If you're not careful, it's easy to define options with conflicting option strings:

```
parser.add_option("-n", "--dry-run", ...)
[...]
parser.add_option("-n", "--noisy", ...)
```

(This is particularly true if you've defined your own `OptionParser` subclass with some standard options.)

Every time you add an option, `optparse` checks for conflicts with existing options. If it finds any, it invokes the current conflict-handling mechanism. You can set the conflict-handling mechanism either in the constructor:

```
parser = OptionParser(..., conflict_handler=handler)
```

or with a separate call:

```
parser.set_conflict_handler(handler)
```

The available conflict handlers are:

**"error"** (default) assume option conflicts are a programming error and raise `OptionConflictError`

**"resolve"** resolve option conflicts intelligently (see below)

As an example, let's define an `OptionParser` that resolves conflicts intelligently and add conflicting options to it:

```
parser = OptionParser(conflict_handler="resolve")
parser.add_option("-n", "--dry-run", ..., help="do no harm")
parser.add_option("-n", "--noisy", ..., help="be noisy")
```

At this point, `optparse` detects that a previously-added option is already using the `-n` option string. Since `conflict_handler` is "resolve", it resolves the situation by removing `-n` from the earlier option's list of option strings. Now `--dry-run` is the only way for the user to activate that option. If the user asks for help, the help message will reflect that:

```
Options:
  --dry-run      do no harm
  [...]
  -n, --noisy    be noisy
```

It's possible to whittle away the option strings for a previously-added option until there are none left, and the user has no way of invoking that option from the command-line. In that case, `optparse` removes that option completely, so it doesn't show up in help text or anywhere else. Carrying on with our existing `OptionParser`:

```
parser.add_option("--dry-run", ..., help="new dry-run option")
```

At this point, the original `-n/--dry-run` option is no longer accessible, so `optparse` removes it, leaving this help text:

```
Options:
  [...]
  -n, --noisy    be noisy
  --dry-run      new dry-run option
```

### Cleanup

`OptionParser` instances have several cyclic references. This should not be a problem for Python's garbage collector, but you may wish to break the cyclic references explicitly by calling `destroy()` on your `OptionParser` once you are done with it. This is particularly useful in long-running applications where large object graphs are reachable from your `OptionParser`.

### Other methods

`OptionParser` supports several other public methods:

`OptionParser.set_usage(usage)`

Set the usage string according to the rules described above for the `usage` constructor keyword argument. Passing `None` sets the default usage string; use `optparse.SUPPRESS_USAGE` to suppress a usage message.

`OptionParser.print_usage(file=None)`

Print the usage message for the current program (`self.usage`) to `file` (default `stdout`). Any occurrence of the string `%prog` in `self.usage` is replaced with the name of the current program. Does nothing if `self.usage` is empty or not defined.

`OptionParser.get_usage()`

Same as `print_usage()` but returns the usage string instead of printing it.

`OptionParser.set_defaults(dest=value, ...)`

Set default values for several option destinations at once. Using `set_defaults()` is the preferred way to set default values for options, since multiple options can share the same destination. For example, if several “mode” options all set the same destination, any one of them can set the default, and the last one wins:

```
parser.add_option("--advanced", action="store_const",
                  dest="mode", const="advanced",
                  default="novice")      # overridden below
parser.add_option("--novice", action="store_const",
                  dest="mode", const="novice",
                  default="advanced")    # overrides above setting
```

To avoid this confusion, use `set_defaults()`:

```
parser.set_defaults(mode="advanced")
parser.add_option("--advanced", action="store_const",
                  dest="mode", const="advanced")
parser.add_option("--novice", action="store_const",
                  dest="mode", const="novice")
```

## 15.5.4 Option Callbacks

When `optparse`’s built-in actions and types aren’t quite enough for your needs, you have two choices: extend `optparse` or define a callback option. Extending `optparse` is more general, but overkill for a lot of simple cases. Quite often a simple callback is all you need.

There are two steps to defining a callback option:

- define the option itself using the "callback" action
- write the callback; this is a function (or method) that takes at least four arguments, as described below

### Defining a callback option

As always, the easiest way to define a callback option is by using the `OptionParser.add_option()` method. Apart from `action`, the only option attribute you must specify is `callback`, the function to call:

```
parser.add_option("-c", action="callback", callback=my_callback)
```

`callback` is a function (or other callable object), so you must have already defined `my_callback()` when you create this callback option. In this simple case, `optparse` doesn’t even know if `-c` takes any arguments, which usually means that the option takes no arguments—the mere presence of `-c` on the command-line is all it needs to know. In some circumstances, though, you might want your callback to consume an arbitrary number of command-line arguments. This is where writing callbacks gets tricky; it’s covered later in this section.

`optparse` always passes four particular arguments to your callback, and it will only pass additional arguments if you specify them via `callback_args` and `callback_kwargs`. Thus, the minimal callback function signature is:

```
def my_callback(option, opt, value, parser):
```

The four arguments to a callback are described below.

There are several other option attributes that you can supply when you define a callback option:

**type** has its usual meaning: as with the "store" or "append" actions, it instructs `optparse` to consume one argument and convert it to `type`. Rather than storing the converted value(s) anywhere, though, `optparse` passes it to your callback function.

**nargs** also has its usual meaning: if it is supplied and  $> 1$ , `optparse` will consume `nargs` arguments, each of which must be convertible to `type`. It then passes a tuple of converted values to your callback.

**callback\_args** a tuple of extra positional arguments to pass to the callback

**callback\_kwargs** a dictionary of extra keyword arguments to pass to the callback

### How callbacks are called

All callbacks are called as follows:

```
func(option, opt_str, value, parser, *args, **kwargs)
```

where

**option** is the `Option` instance that's calling the callback

**opt\_str** is the option string seen on the command-line that's triggering the callback. (If an abbreviated long option was used, `opt_str` will be the full, canonical option string—e.g. if the user puts `--foo` on the command-line as an abbreviation for `--foobar`, then `opt_str` will be `"--foobar"`.)

**value** is the argument to this option seen on the command-line. `optparse` will only expect an argument if `type` is set; the type of `value` will be the type implied by the option's type. If `type` for this option is `None` (no argument expected), then `value` will be `None`. If `nargs > 1`, `value` will be a tuple of values of the appropriate type.

**parser** is the `OptionParser` instance driving the whole thing, mainly useful because you can access some other interesting data through its instance attributes:

**parser.largs** the current list of leftover arguments, ie. arguments that have been consumed but are neither options nor option arguments. Feel free to modify `parser.largs`, e.g. by adding more arguments to it. (This list will become `args`, the second return value of `parse_args()`.)

**parser.rargs** the current list of remaining arguments, ie. with `opt_str` and `value` (if applicable) removed, and only the arguments following them still there. Feel free to modify `parser.rargs`, e.g. by consuming more arguments.

**parser.values** the object where option values are by default stored (an instance of `optparse.OptionValues`). This lets callbacks use the same mechanism as the rest of `optparse` for storing option values; you don't need to mess around with globals or closures. You can also access or modify the value(s) of any options already encountered on the command-line.

**args** is a tuple of arbitrary positional arguments supplied via the `callback_args` option attribute.

**kwargs** is a dictionary of arbitrary keyword arguments supplied via `callback_kwargs`.

### Raising errors in a callback

The callback function should raise `OptionValueError` if there are any problems with the option or its argument(s). `optparse` catches this and terminates the program, printing the error message you supply to `stderr`. Your message should be clear, concise, accurate, and mention the option at fault. Otherwise, the user will have a hard time figuring out what he did wrong.

### Callback example 1: trivial callback

Here's an example of a callback option that takes no arguments, and simply records that the option was seen:

```
def record_foo_seen(option, opt_str, value, parser):
    parser.values.saw_foo = True
```

```
parser.add_option("--foo", action="callback", callback=record_foo_seen)
```

Of course, you could do that with the "store\_true" action.

### Callback example 2: check option order

Here's a slightly more interesting example: record the fact that `-a` is seen, but blow up if it comes after `-b` in the command-line.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use -a after -b")
    parser.values.a = 1
[...]
parser.add_option("-a", action="callback", callback=check_order)
parser.add_option("-b", action="store_true", dest="b")
```

### Callback example 3: check option order (generalized)

If you want to re-use this callback for several similar options (set a flag, but blow up if `-b` has already been seen), it needs a bit of work: the error message and the flag that it sets must be generalized.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use %s after -b" % opt_str)
    setattr(parser.values, option.dest, 1)
[...]
parser.add_option("-a", action="callback", callback=check_order, dest='a')
parser.add_option("-b", action="store_true", dest="b")
parser.add_option("-c", action="callback", callback=check_order, dest='c')
```

### Callback example 4: check arbitrary condition

Of course, you could put any condition in there—you're not limited to checking the values of already-defined options. For example, if you have options that should not be called when the moon is full, all you have to do is this:

```
def check_moon(option, opt_str, value, parser):
    if is_moon_full():
        raise OptionValueError("%s option invalid when moon is full"
                                % opt_str)
    setattr(parser.values, option.dest, 1)
[...]
parser.add_option("--foo",
                  action="callback", callback=check_moon, dest="foo")
```

(The definition of `is_moon_full()` is left as an exercise for the reader.)

### Callback example 5: fixed arguments

Things get slightly more interesting when you define callback options that take a fixed number of arguments. Specifying that a callback option takes arguments is similar to defining a "store" or "append" option: if you define

`type`, then the option takes one argument that must be convertible to that type; if you further define `nargs`, then the option takes `nargs` arguments.

Here's an example that just emulates the standard "store" action:

```
def store_value(option, opt_str, value, parser):
    setattr(parser.values, option.dest, value)
[...]
parser.add_option("--foo",
                  action="callback", callback=store_value,
                  type="int", nargs=3, dest="foo")
```

Note that `optparse` takes care of consuming 3 arguments and converting them to integers for you; all you have to do is store them. (Or whatever; obviously you don't need a callback for this example.)

### Callback example 6: variable arguments

Things get hairy when you want an option to take a variable number of arguments. For this case, you must write a callback, as `optparse` doesn't provide any built-in capabilities for it. And you have to deal with certain intricacies of conventional Unix command-line parsing that `optparse` normally handles for you. In particular, callbacks should implement the conventional rules for bare `--` and `-` arguments:

- either `--` or `-` can be option arguments
- bare `--` (if not the argument to some option): halt command-line processing and discard the `--`
- bare `-` (if not the argument to some option): halt command-line processing but keep the `-` (append it to `parser.largs`)

If you want an option that takes a variable number of arguments, there are several subtle, tricky issues to worry about. The exact implementation you choose will be based on which trade-offs you're willing to make for your application (which is why `optparse` doesn't support this sort of thing directly).

Nevertheless, here's a stab at a callback for an option with variable arguments:

```
def vararg_callback(option, opt_str, value, parser):
    assert value is None
    value = []

    def floatable(str):
        try:
            float(str)
            return True
        except ValueError:
            return False

    for arg in parser.rargs:
        # stop on --foo like options
        if arg[:2] == "--" and len(arg) > 2:
            break
        # stop on -a, but not on -3 or -3.0
        if arg[:1] == "-" and len(arg) > 1 and not floatable(arg):
            break
        value.append(arg)

    del parser.rargs[:len(value)]
    setattr(parser.values, option.dest, value)
```

```
[...]
parser.add_option("-c", "--callback", dest="vararg_attr",
                 action="callback", callback=vararg_callback)
```

## 15.5.5 Extending optparse

Since the two major controlling factors in how `optparse` interprets command-line options are the action and type of each option, the most likely direction of extension is to add new actions and new types.

### Adding new types

To add new types, you need to define your own subclass of `optparse`'s `Option` class. This class has a couple of attributes that define `optparse`'s types: `TYPES` and `TYPE_CHECKER`.

#### `Option.TYPES`

A tuple of type names; in your subclass, simply define a new tuple `TYPES` that builds on the standard one.

#### `Option.TYPE_CHECKER`

A dictionary mapping type names to type-checking functions. A type-checking function has the following signature:

```
def check_mytype(option, opt, value)
```

where `option` is an `Option` instance, `opt` is an option string (e.g., `-f`), and `value` is the string from the command line that must be checked and converted to your desired type. `check_mytype()` should return an object of the hypothetical type `mytype`. The value returned by a type-checking function will wind up in the `OptionValues` instance returned by `OptionParser.parse_args()`, or be passed to a callback as the `value` parameter.

Your type-checking function should raise `OptionValueError` if it encounters any problems. `OptionValueError` takes a single string argument, which is passed as-is to `OptionParser.error()` method, which in turn prepends the program name and the string `"error: "` and prints everything to `stderr` before terminating the process.

Here's a silly example that demonstrates adding a `"complex"` option type to parse Python-style complex numbers on the command line. (This is even sillier than it used to be, because `optparse` 1.3 added built-in support for complex numbers, but never mind.)

First, the necessary imports:

```
from copy import copy
from optparse import Option, OptionValueError
```

You need to define your type-checker first, since it's referred to later (in the `TYPE_CHECKER` class attribute of your `Option` subclass):

```
def check_complex(option, opt, value):
    try:
        return complex(value)
    except ValueError:
        raise OptionValueError(
            "option %s: invalid complex value: %r" % (opt, value))
```

Finally, the `Option` subclass:

```
class MyOption (Option):
    TYPES = Option.TYPES + ("complex",)
```

```
TYPE_CHECKER = copy(Option.TYPE_CHECKER)
TYPE_CHECKER["complex"] = check_complex
```

(If we didn't make a `copy()` of `Option.TYPE_CHECKER`, we would end up modifying the `TYPE_CHECKER` attribute of `optparse`'s `Option` class. This being Python, nothing stops you from doing that except good manners and common sense.)

That's it! Now you can write a script that uses the new option type just like any other `optparse`-based script, except you have to instruct your `OptionParser` to use `MyOption` instead of `Option`:

```
parser = OptionParser(option_class=MyOption)
parser.add_option("-c", type="complex")
```

Alternately, you can build your own option list and pass it to `OptionParser`; if you don't use `add_option()` in the above way, you don't need to tell `OptionParser` which option class to use:

```
option_list = [MyOption("-c", action="store", type="complex", dest="c")]
parser = OptionParser(option_list=option_list)
```

### Adding new actions

Adding new actions is a bit trickier, because you have to understand that `optparse` has a couple of classifications for actions:

“**store**” actions actions that result in `optparse` storing a value to an attribute of the current `OptionValues` instance; these options require a `dest` attribute to be supplied to the `Option` constructor.

“**typed**” actions actions that take a value from the command line and expect it to be of a certain type; or rather, a string that can be converted to a certain type. These options require a `type` attribute to the `Option` constructor.

These are overlapping sets: some default “store” actions are `"store"`, `"store_const"`, `"append"`, and `"count"`, while the default “typed” actions are `"store"`, `"append"`, and `"callback"`.

When you add an action, you need to categorize it by listing it in at least one of the following class attributes of `Option` (all are lists of strings):

#### `Option.ACTIONS`

All actions must be listed in `ACTIONS`.

#### `Option.STORE_ACTIONS`

“store” actions are additionally listed here.

#### `Option.TYPED_ACTIONS`

“typed” actions are additionally listed here.

#### `Option.ALWAYS_TYPED_ACTIONS`

Actions that always take a type (i.e. whose options always take a value) are additionally listed here. The only effect of this is that `optparse` assigns the default type, `"string"`, to options with no explicit type whose action is listed in `ALWAYS_TYPED_ACTIONS`.

In order to actually implement your new action, you must override `Option`'s `take_action()` method and add a case that recognizes your action.

For example, let's add an `"extend"` action. This is similar to the standard `"append"` action, but instead of taking a single value from the command-line and appending it to an existing list, `"extend"` will take multiple values in a single comma-delimited string, and extend an existing list with them. That is, if `--names` is an `"extend"` option of type `"string"`, the command line

```
--names=foo,bar --names blah --names ding,dong
```

would result in a list

```
["foo", "bar", "blah", "ding", "dong"]
```

Again we define a subclass of `Option`:

```
class MyOption(Option):

    ACTIONS = Option.ACTIONS + ("extend",)
    STORE_ACTIONS = Option.STORE_ACTIONS + ("extend",)
    TYPED_ACTIONS = Option.TYPED_ACTIONS + ("extend",)
    ALWAYS_TYPED_ACTIONS = Option.ALWAYS_TYPED_ACTIONS + ("extend",)

    def take_action(self, action, dest, opt, value, values, parser):
        if action == "extend":
            lvalue = value.split(",")
            values.ensure_value(dest, []).extend(lvalue)
        else:
            Option.take_action(
                self, action, dest, opt, value, values, parser)
```

Features of note:

- "extend" both expects a value on the command-line and stores that value somewhere, so it goes in both `STORE_ACTIONS` and `TYPED_ACTIONS`.
- to ensure that `optparse` assigns the default type of "string" to "extend" actions, we put the "extend" action in `ALWAYS_TYPED_ACTIONS` as well.
- `MyOption.take_action()` implements just this one new action, and passes control back to `Option.take_action()` for the standard `optparse` actions.
- `values` is an instance of the `optparse.Values` class, which provides the very useful `ensure_value()` method. `ensure_value()` is essentially `getattr()` with a safety valve; it is called as `values.ensure_value(attr, value)`

If the `attr` attribute of `values` doesn't exist or is `None`, then `ensure_value()` first sets it to `value`, and then returns `value`. This is very handy for actions like "extend", "append", and "count", all of which accumulate data in a variable and expect that variable to be of a certain type (a list for the first two, an integer for the latter). Using `ensure_value()` means that scripts using your action don't have to worry about setting a default value for the option destinations in question; they can just leave the default as `None` and `ensure_value()` will take care of getting it right when it's needed.

## 15.6 getopt — C-style parser for command line options

Source code: [Lib/getopt.py](#)

---

**Note:** The `getopt` module is a parser for command line options whose API is designed to be familiar to users of the C `getopt()` function. Users who are unfamiliar with the C `getopt()` function or who would like to write less code and get better help and error messages should consider using the `argparse` module instead.

---

This module helps scripts to parse the command line arguments in `sys.argv`. It supports the same conventions as the Unix `getopt()` function (including the special meanings of arguments of the form '-' and '--'). Long options similar to those supported by GNU software may be used as well via an optional third argument.

This module provides two functions and an exception:

`getopt.getopt` (*args*, *options* [, *long\_options* ])

Parses command line options and parameter list. *args* is the argument list to be parsed, without the leading reference to the running program. Typically, this means `sys.argv[1:]`. *options* is the string of option letters that the script wants to recognize, with options that require an argument followed by a colon (':'); i.e., the same format that Unix `getopt()` uses).

---

**Note:** Unlike GNU `getopt()`, after a non-option argument, all further arguments are considered also non-options. This is similar to the way non-GNU Unix systems work.

---

*long\_options*, if specified, must be a list of strings with the names of the long options which should be supported. The leading '--' characters should not be included in the option name. Long options which require an argument should be followed by an equal sign ('='). Optional arguments are not supported. To accept only long options, *options* should be an empty string. Long options on the command line can be recognized so long as they provide a prefix of the option name that matches exactly one of the accepted options. For example, if *long\_options* is ['foo', 'frob'], the option --fo will match as --foo, but --f will not match uniquely, so `GetoptError` will be raised.

The return value consists of two elements: the first is a list of (*option*, *value*) pairs; the second is the list of program arguments left after the option list was stripped (this is a trailing slice of *args*). Each option-and-value pair returned has the option as its first element, prefixed with a hyphen for short options (e.g., '-x') or two hyphens for long options (e.g., '--long-option'), and the option argument as its second element, or an empty string if the option has no argument. The options occur in the list in the same order in which they were found, thus allowing multiple occurrences. Long and short options may be mixed.

`getopt.gnu_getopt` (*args*, *options* [, *long\_options* ])

This function works like `getopt()`, except that GNU style scanning mode is used by default. This means that option and non-option arguments may be intermixed. The `getopt()` function stops processing options as soon as a non-option argument is encountered.

If the first character of the option string is '+', or if the environment variable `POSIIXLY_CORRECT` is set, then option processing stops as soon as a non-option argument is encountered. New in version 2.3.

**exception** `getopt.GetoptError`

This is raised when an unrecognized option is found in the argument list or when an option requiring an argument is given none. The argument to the exception is a string indicating the cause of the error. For long options, an argument given to an option which does not require one will also cause this exception to be raised. The attributes `msg` and `opt` give the error message and related option; if there is no specific option to which the exception relates, `opt` is an empty string. Changed in version 1.6: Introduced `GetoptError` as a synonym for `error`.

**exception** `getopt.error`

Alias for `GetoptError`; for backward compatibility.

An example using only Unix style options:

```
>>> import getopt
>>> args = '-a -b -cfoo -d bar a1 a2'.split()
>>> args
['-a', '-b', '-cfoo', '-d', 'bar', 'a1', 'a2']
>>> optlist, args = getopt.getopt(args, 'abc:d:')
>>> optlist
[('-a', ''), ('-b', ''), ('-c', 'foo'), ('-d', 'bar')]
>>> args
['a1', 'a2']
```

Using long option names is equally easy:

```
>>> s = '--condition=foo --testing --output-file abc.def -x a1 a2'
>>> args = s.split()
```

```
>>> args
[--condition=foo', '--testing', '--output-file', 'abc.def', '-x', 'a1', 'a2']
>>> optlist, args = getopt.getopt(args, 'x', [
...     'condition=', 'output-file=', 'testing'])
>>> optlist
(['--condition', 'foo'), ('--testing', ''), ('--output-file', 'abc.def'), ('-x', '')]
>>> args
['a1', 'a2']
```

In a script, typical usage is something like this:

```
import getopt, sys

def main():
    try:
        opts, args = getopt.getopt(sys.argv[1:], "ho:v", ["help", "output="])
    except getopt.GetoptError, err:
        # print help information and exit:
        print str(err) # will print something like "option -a not recognized"
        usage()
        sys.exit(2)
    output = None
    verbose = False
    for o, a in opts:
        if o == "-v":
            verbose = True
        elif o in ("-h", "--help"):
            usage()
            sys.exit()
        elif o in ("-o", "--output"):
            output = a
        else:
            assert False, "unhandled option"
    # ...

if __name__ == "__main__":
    main()
```

Note that an equivalent command line interface could be produced with less code and more informative help and error messages by using the `argparse` module:

```
import argparse

if __name__ == '__main__':
    parser = argparse.ArgumentParser()
    parser.add_argument('-o', '--output')
    parser.add_argument('-v', dest='verbose', action='store_true')
    args = parser.parse_args()
    # ... do something with args.output ...
    # ... do something with args.verbose ..
```

**See Also:**

**Module `argparse`** Alternative command line option and argument parsing library.

## 15.7 logging — Logging facility for Python

### Important

This page contains the API reference information. For tutorial information and discussion of more advanced topics, see

- *Basic Tutorial*
- *Advanced Tutorial*
- *Logging Cookbook*

New in version 2.3. This module defines functions and classes which implement a flexible event logging system for applications and libraries.

The key benefit of having the logging API provided by a standard library module is that all Python modules can participate in logging, so your application log can include your own messages integrated with messages from third-party modules.

The module provides a lot of functionality and flexibility. If you are unfamiliar with logging, the best way to get to grips with it is to see the tutorials (see the links on the right).

The basic classes defined by the module, together with their functions, are listed below.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.
- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.

### 15.7.1 Logger Objects

Loggers have the following attributes and methods. Note that Loggers are never instantiated directly, but always through the module-level function `logging.getLogger(name)`. Multiple calls to `getLogger()` with the same name will always return a reference to the same Logger object.

The `name` is potentially a period-separated hierarchical value, like `foo.bar.baz` (though it could also be just plain `foo`, for example). Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of `foo`, loggers with names of `foo.bar`, `foo.bar.baz`, and `foo.bam` are all descendants of `foo`. The logger name hierarchy is analogous to the Python package hierarchy, and identical to it if you organise your loggers on a per-module basis using the recommended construction `logging.getLogger(__name__)`. That's because in a module, `__name__` is the module's name in the Python package namespace.

**class** `logging.Logger`

`Logger.propagate`

If this evaluates to true, logging messages are passed by this logger and by its child loggers to the handlers of higher level (ancestor) loggers. Messages are passed directly to the ancestor loggers' handlers - neither the level nor filters of the ancestor loggers in question are considered.

If this evaluates to false, logging messages are not passed to the handlers of ancestor loggers.

The constructor sets this attribute to `True`.

`Logger.setLevel(lvl)`

Sets the threshold for this logger to `lvl`. Logging messages which are less severe than `lvl` will be ignored. When a logger is created, the level is set to `NOTSET` (which causes all messages to be processed when the logger is

the root logger, or delegation to the parent when the logger is a non-root logger). Note that the root logger is created with level `WARNING`.

The term ‘delegation to the parent’ means that if a logger has a level of `NOTSET`, its chain of ancestor loggers is traversed until either an ancestor with a level other than `NOTSET` is found, or the root is reached.

If an ancestor is found with a level other than `NOTSET`, then that ancestor’s level is treated as the effective level of the logger where the ancestor search began, and is used to determine how a logging event is handled.

If the root is reached, and it has a level of `NOTSET`, then all messages will be processed. Otherwise, the root’s level will be used as the effective level.

`Logger.isEnabledFor(lvl)`

Indicates if a message of severity *lvl* would be processed by this logger. This method checks first the module-level level set by `logging.disable(lvl)` and then the logger’s effective level as determined by `getEffectiveLevel()`.

`Logger.getEffectiveLevel()`

Indicates the effective level for this logger. If a value other than `NOTSET` has been set using `setLevel()`, it is returned. Otherwise, the hierarchy is traversed towards the root until a value other than `NOTSET` is found, and that value is returned.

`Logger.getChild(suffix)`

Returns a logger which is a descendant to this logger, as determined by the suffix. Thus, `logging.getLogger('abc').getChild('def.ghi')` would return the same logger as would be returned by `logging.getLogger('abc.def.ghi')`. This is a convenience method, useful when the parent logger is named using e.g. `__name__` rather than a literal string. New in version 2.7.

`Logger.debug(msg, *args, **kwargs)`

Logs a message with level `DEBUG` on this logger. The *msg* is the message format string, and the *args* are the arguments which are merged into *msg* using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are two keyword arguments in *kwargs* which are inspected: *exc\_info* which, if it does not evaluate as false, causes exception information to be added to the logging message. If an exception tuple (in the format returned by `sys.exc_info()`) is provided, it is used; otherwise, `sys.exc_info()` is called to get the exception information.

The second keyword argument is *extra* which can be used to pass a dictionary which is used to populate the `__dict__` of the `LogRecord` created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```
FORMAT = '%(asctime)-15s %(clientip)s %(user)-8s %(message)s'
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logger = logging.getLogger('tcpserver')
logger.warning('Protocol problem: %s', 'connection reset', extra=d)
```

would print something like

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs Protocol problem: connection reset
```

The keys in the dictionary passed in *extra* should not clash with the keys used by the logging system. (See the `Formatter` documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the `Formatter` has been set up with a format string which expects ‘clientip’ and ‘user’ in the attribute dictionary of the `LogRecord`. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to pass the *extra* dictionary with these keys.

While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized `Formatters` would be used with particular `Handlers`.

`Logger.info(msg, *args, **kwargs)`

Logs a message with level INFO on this logger. The arguments are interpreted as for `debug()`.

`Logger.warning(msg, *args, **kwargs)`

Logs a message with level WARNING on this logger. The arguments are interpreted as for `debug()`.

`Logger.error(msg, *args, **kwargs)`

Logs a message with level ERROR on this logger. The arguments are interpreted as for `debug()`.

`Logger.critical(msg, *args, **kwargs)`

Logs a message with level CRITICAL on this logger. The arguments are interpreted as for `debug()`.

`Logger.log(lvl, msg, *args, **kwargs)`

Logs a message with integer level *lvl* on this logger. The other arguments are interpreted as for `debug()`.

`Logger.exception(msg, *args)`

Logs a message with level ERROR on this logger. The arguments are interpreted as for `debug()`. Exception info is added to the logging message. This method should only be called from an exception handler.

`Logger.addFilter(filt)`

Adds the specified filter *filt* to this logger.

`Logger.removeFilter(filt)`

Removes the specified filter *filt* from this logger.

`Logger.filter(record)`

Applies this logger's filters to the record and returns a true value if the record is to be processed.

`Logger.addHandler(hdlr)`

Adds the specified handler *hdlr* to this logger.

`Logger.removeHandler(hdlr)`

Removes the specified handler *hdlr* from this logger.

`Logger.findCaller()`

Finds the caller's source filename and line number. Returns the filename, line number and function name as a 3-element tuple. Changed in version 2.4: The function name was added. In earlier versions, the filename and line number were returned as a 2-element tuple.

`Logger.handle(record)`

Handles a record by passing it to all handlers associated with this logger and its ancestors (until a false value of *propagate* is found). This method is used for unpickled records received from a socket, as well as those created locally. Logger-level filtering is applied using `filter()`.

`Logger.makeRecord(name, lvl, fn, lno, msg, args, exc_info, func=None, extra=None)`

This is a factory method which can be overridden in subclasses to create specialized `LogRecord` instances. Changed in version 2.5: *func* and *extra* were added.

## 15.7.2 Handler Objects

Handlers have the following attributes and methods. Note that `Handler` is never instantiated directly; this class acts as a base for more useful subclasses. However, the `__init__()` method in subclasses needs to call `Handler.__init__()`.

- `Handler.__init__ (level=NOTSET)`  
 Initializes the `Handler` instance by setting its level, setting the list of filters to the empty list and creating a lock (using `createLock()`) for serializing access to an I/O mechanism.
- `Handler.createLock()`  
 Initializes a thread lock which can be used to serialize access to underlying I/O functionality which may not be threadsafe.
- `Handler.acquire()`  
 Acquires the thread lock created with `createLock()`.
- `Handler.release()`  
 Releases the thread lock acquired with `acquire()`.
- `Handler.setLevel (lvl)`  
 Sets the threshold for this handler to *lvl*. Logging messages which are less severe than *lvl* will be ignored. When a handler is created, the level is set to `NOTSET` (which causes all messages to be processed).
- `Handler.setFormatter (form)`  
 Sets the `Formatter` for this handler to *form*.
- `Handler.addFilter (filt)`  
 Adds the specified filter *filt* to this handler.
- `Handler.removeFilter (filt)`  
 Removes the specified filter *filt* from this handler.
- `Handler.filter (record)`  
 Applies this handler's filters to the record and returns a true value if the record is to be processed.
- `Handler.flush()`  
 Ensure all logging output has been flushed. This version does nothing and is intended to be implemented by subclasses.
- `Handler.close()`  
 Tidy up any resources used by the handler. This version does no output but removes the handler from an internal list of handlers which is closed when `shutdown()` is called. Subclasses should ensure that this gets called from overridden `close()` methods.
- `Handler.handle (record)`  
 Conditionally emits the specified logging record, depending on filters which may have been added to the handler. Wraps the actual emission of the record with acquisition/release of the I/O thread lock.
- `Handler.handleError (record)`  
 This method should be called from handlers when an exception is encountered during an `emit()` call. If the module-level attribute `raiseExceptions` is `False`, exceptions get silently ignored. This is what is mostly wanted for a logging system - most users will not care about errors in the logging system, they are more interested in application errors. You could, however, replace this with a custom handler if you wish. The specified record is the one which was being processed when the exception occurred. (The default value of `raiseExceptions` is `True`, as that is more useful during development).
- `Handler.format (record)`  
 Do formatting for a record - if a formatter is set, use it. Otherwise, use the default formatter for the module.
- `Handler.emit (record)`  
 Do whatever it takes to actually log the specified logging record. This version is intended to be implemented by subclasses and so raises a `NotImplementedError`.

For a list of handlers included as standard, see `logging.handlers`.

### 15.7.3 Formatter Objects

`Formatter` objects have the following attributes and methods. They are responsible for converting a `LogRecord` to (usually) a string which can be interpreted by either a human or an external system. The base `Formatter` allows a formatting string to be specified. If none is supplied, the default value of `'%(message)s'` is used.

A `Formatter` can be initialized with a format string which makes use of knowledge of the `LogRecord` attributes - such as the default value mentioned above making use of the fact that the user's message and arguments are pre-formatted into a `LogRecord`'s `message` attribute. This format string contains standard Python %-style mapping keys. See section *String Formatting Operations* for more information on string formatting.

The useful mapping keys in a `LogRecord` are given in the section on *LogRecord attributes*.

**class** `logging.Formatter` (*fmt=None, datefmt=None*)

Returns a new instance of the `Formatter` class. The instance is initialized with a format string for the message as a whole, as well as a format string for the date/time portion of a message. If no *fmt* is specified, `'%(message)s'` is used. If no *datefmt* is specified, the ISO8601 date format is used.

**format** (*record*)

The record's attribute dictionary is used as the operand to a string formatting operation. Returns the resulting string. Before formatting the dictionary, a couple of preparatory steps are carried out. The `message` attribute of the record is computed using `msg % args`. If the formatting string contains `'(asctime)'`, `formatTime()` is called to format the event time. If there is exception information, it is formatted using `formatException()` and appended to the message. Note that the formatted exception information is cached in attribute `exc_text`. This is useful because the exception information can be pickled and sent across the wire, but you should be careful if you have more than one `Formatter` subclass which customizes the formatting of exception information. In this case, you will have to clear the cached value after a formatter has done its formatting, so that the next formatter to handle the event doesn't use the cached value but recalculates it afresh.

**formatTime** (*record, datefmt=None*)

This method should be called from `format()` by a formatter which wants to make use of a formatted time. This method can be overridden in formatters to provide for any specific requirement, but the basic behavior is as follows: if *datefmt* (a string) is specified, it is used with `time.strftime()` to format the creation time of the record. Otherwise, the ISO8601 format is used. The resulting string is returned.

This function uses a user-configurable function to convert the creation time to a tuple. By default, `time.localtime()` is used; to change this for a particular formatter instance, set the `converter` attribute to a function with the same signature as `time.localtime()` or `time.gmtime()`. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the `converter` attribute in the `Formatter` class.

**formatException** (*exc\_info*)

Formats the specified exception information (a standard exception tuple as returned by `sys.exc_info()`) as a string. This default implementation just uses `traceback.print_exception()`. The resulting string is returned.

### 15.7.4 Filter Objects

`Filters` can be used by `Handlers` and `Loggers` for more sophisticated filtering than is provided by levels. The base filter class only allows events which are below a certain point in the logger hierarchy. For example, a filter initialized with 'A.B' will allow events logged by loggers 'A.B', 'A.B.C', 'A.B.C.D', 'A.B.D' etc. but not 'A.BB', 'B.A.B' etc. If initialized with the empty string, all events are passed.

**class** `logging.Filter` (*name=''*)

Returns an instance of the `Filter` class. If *name* is specified, it names a logger which, together with its children, will have its events allowed through the filter. If *name* is the empty string, allows every event.

**filter** (*record*)

Is the specified record to be logged? Returns zero for no, nonzero for yes. If deemed appropriate, the record may be modified in-place by this method.

Note that filters attached to handlers are consulted whenever an event is emitted by the handler, whereas filters attached to loggers are consulted whenever an event is logged to the handler (using `debug()`, `info()`, etc.) This means that events which have been generated by descendant loggers will not be filtered by a logger's filter setting, unless the filter has also been applied to those descendant loggers.

You don't actually need to subclass `Filter`: you can pass any instance which has a `filter` method with the same semantics.

Although filters are used primarily to filter records based on more sophisticated criteria than levels, they get to see every record which is processed by the handler or logger they're attached to: this can be useful if you want to do things like counting how many records were processed by a particular logger or handler, or adding, changing or removing attributes in the `LogRecord` being processed. Obviously changing the `LogRecord` needs to be done with some care, but it does allow the injection of contextual information into logs (see *filters-contextual*).

### 15.7.5 LogRecord Objects

`LogRecord` instances are created automatically by the `Logger` every time something is logged, and can be created manually via `makeLogRecord()` (for example, from a pickled event received over the wire).

**class** `logging.LogRecord` (*name, level, pathname, lineno, msg, args, exc\_info, func=None*)

Contains all the information pertinent to the event being logged.

The primary information is passed in `msg` and `args`, which are combined using `msg % args` to create the message field of the record.

#### Parameters

- **name** – The name of the logger used to log the event represented by this `LogRecord`.
- **level** – The numeric level of the logging event (one of `DEBUG`, `INFO` etc.) Note that this is converted to *two* attributes of the `LogRecord`: `levelname` for the numeric value and `levelname` for the corresponding level name.
- **pathname** – The full pathname of the source file where the logging call was made.
- **lineno** – The line number in the source file where the logging call was made.
- **msg** – The event description message, possibly a format string with placeholders for variable data.
- **args** – Variable data to merge into the `msg` argument to obtain the event description.
- **exc\_info** – An exception tuple with the current exception information, or `None` if no exception information is available.
- **func** – The name of the function or method from which the logging call was invoked.

Changed in version 2.5: `func` was added.

#### `getMessage()`

Returns the message for this `LogRecord` instance after merging any user-supplied arguments with the message. If the user-supplied message argument to the logging call is not a string, `str()` is called on it to convert it to a string. This allows use of user-defined classes as messages, whose `__str__` method can return the actual format string to be used.

### 15.7.6 LogRecord attributes

The LogRecord has a number of attributes, most of which are derived from the parameters to the constructor. (Note that the names do not always correspond exactly between the LogRecord constructor parameters and the LogRecord attributes.) These attributes can be used to merge data from the record into the format string. The following table lists (in alphabetical order) the attribute names, their meanings and the corresponding placeholder in a %-style format string.

At-tribute name	Format	Description
args	You shouldn't need to format this yourself.	The tuple of arguments merged into <code>msg</code> to produce <code>message</code> .
asctime	<code>%(asctime)s</code>	Human-readable time when the <code>LogRecord</code> was created. By default this is of the form '2003-07-08 16:49:45,896' (the numbers after the comma are millisecond portion of the time).
created	<code>%(created)f</code>	Time when the <code>LogRecord</code> was created (as returned by <code>time.time()</code> ).
exc_info	You shouldn't need to format this yourself.	Exception tuple (à la <code>sys.exc_info</code> ) or, if no exception has occurred, <code>None</code> .
file-name	<code>%(filename)s</code>	Filename portion of <code>pathname</code> .
func-Name	<code>%(funcName)s</code>	Name of function containing the logging call.
level-name	<code>%(levelname)s</code>	Text logging level for the message ('DEBUG', 'INFO', 'WARNING', 'ERROR', 'CRITICAL').
levelno	<code>%(levelno)s</code>	Numeric logging level for the message (DEBUG, INFO, WARNING, ERROR, CRITICAL).
lineno	<code>%(lineno)d</code>	Source line number where the logging call was issued (if available).
module	<code>%(module)s</code>	Module (name portion of <code>filename</code> ).
msecs	<code>%(msecs)d</code>	Millisecond portion of the time when the <code>LogRecord</code> was created.
message	<code>%(message)s</code>	The logged message, computed as <code>msg % args</code> . This is set when <code>Formatter.format()</code> is invoked.
msg	You shouldn't need to format this yourself.	The format string passed in the original logging call. Merged with <code>args</code> to produce <code>message</code> , or an arbitrary object (see <i>arbitrary-object-messages</i> ).
name	<code>%(name)s</code>	Name of the logger used to log the call.
path-name	<code>%(pathname)s</code>	Full pathname of the source file where the logging call was issued (if available).
process	<code>%(process)d</code>	Process ID (if available).
process-Name	<code>%(processName)s</code>	Process name (if available).
relative-Created	<code>%(relativeCreated)f</code>	Time in milliseconds when the <code>LogRecord</code> was created, relative to the time the logging module was loaded.
thread	<code>%(thread)d</code>	Thread ID (if available).
thread-Name	<code>%(threadName)s</code>	Thread name (if available).

Changed in version 2.5: `funcName` was added.Changed in version 2.6: `processName` was added.

### 15.7.7 LoggerAdapter Objects

`LoggerAdapter` instances are used to conveniently pass contextual information into logging calls. For a usage

example, see the section on *adding contextual information to your logging output*. New in version 2.6.

**class** `logging.LoggerAdapter` (*logger, extra*)

Returns an instance of `LoggerAdapter` initialized with an underlying `Logger` instance and a dict-like object.

**process** (*msg, kwargs*)

Modifies the message and/or keyword arguments passed to a logging call in order to insert contextual information. This implementation takes the object passed as *extra* to the constructor and adds it to *kwargs* using key 'extra'. The return value is a (*msg, kwargs*) tuple which has the (possibly modified) versions of the arguments passed in.

In addition to the above, `LoggerAdapter` supports the following methods of `Logger`, i.e. `debug()`, `info()`, `warning()`, `error()`, `exception()`, `critical()`, `log()`, `isEnabledFor()`, `getEffectiveLevel()`, `setLevel()`, `handlers`. These methods have the same signatures as their counterparts in `Logger`, so you can use the two types of instances interchangeably. Changed in version 2.7: The `isEnabledFor()` method was added to `LoggerAdapter`. This method delegates to the underlying logger.

### 15.7.8 Thread Safety

The logging module is intended to be thread-safe without any special work needing to be done by its clients. It achieves this though using threading locks; there is one lock to serialize access to the module's shared data, and each handler also creates a lock to serialize access to its underlying I/O.

If you are implementing asynchronous signal handlers using the `signal` module, you may not be able to use logging from within such handlers. This is because lock implementations in the `threading` module are not always re-entrant, and so cannot be invoked from such signal handlers.

### 15.7.9 Module-Level Functions

In addition to the classes described above, there are a number of module-level functions.

`logging.getLogger` (*[name]*)

Return a logger with the specified name or, if no name is specified, return a logger which is the root logger of the hierarchy. If specified, the name is typically a dot-separated hierarchical name like "a", "a.b" or "a.b.c.d". Choice of these names is entirely up to the developer who is using logging.

All calls to this function with a given name return the same logger instance. This means that logger instances never need to be passed between different parts of an application.

`logging.getLoggerClass` ()

Return either the standard `Logger` class, or the last class passed to `setLoggerClass()`. This function may be called from within a new class definition, to ensure that installing a customised `Logger` class will not undo customisations already applied by other code. For example:

```
class MyLogger(logging.getLoggerClass()):
    # ... override behaviour here
```

`logging.debug` (*msg*, *\*args*, *\*\*kwargs*)]])

Logs a message with level `DEBUG` on the root logger. The *msg* is the message format string, and the *args* are the arguments which are merged into *msg* using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are two keyword arguments in *kwargs* which are inspected: *exc\_info* which, if it does not evaluate as false, causes exception information to be added to the logging message. If an exception tuple (in the format returned by `sys.exc_info()`) is provided, it is used; otherwise, `sys.exc_info()` is called to get the exception information.

The other optional keyword argument is *extra* which can be used to pass a dictionary which is used to populate the `__dict__` of the `LogRecord` created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```
FORMAT = "%(asctime)-15s %(clientip)s %(user)-8s %(message)s"
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logging.warning("Protocol problem: %s", "connection reset", extra=d)
```

would print something like:

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs Protocol problem: connection reset
```

The keys in the dictionary passed in *extra* should not clash with the keys used by the logging system. (See the `Formatter` documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the `Formatter` has been set up with a format string which expects 'clientip' and 'user' in the attribute dictionary of the `LogRecord`. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to pass the *extra* dictionary with these keys.

While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized `Formatters` would be used with particular `Handlers`. Changed in version 2.5: *extra* was added.

```
logging.info(msg[, *args[, **kwargs]])
```

Logs a message with level INFO on the root logger. The arguments are interpreted as for `debug()`.

```
logging.warning(msg[, *args[, **kwargs]])
```

Logs a message with level WARNING on the root logger. The arguments are interpreted as for `debug()`.

```
logging.error(msg[, *args[, **kwargs]])
```

Logs a message with level ERROR on the root logger. The arguments are interpreted as for `debug()`.

```
logging.critical(msg[, *args[, **kwargs]])
```

Logs a message with level CRITICAL on the root logger. The arguments are interpreted as for `debug()`.

```
logging.exception(msg[, *args])
```

Logs a message with level ERROR on the root logger. The arguments are interpreted as for `debug()`. Exception info is added to the logging message. This function should only be called from an exception handler.

```
logging.log(level, msg[, *args[, **kwargs]])
```

Logs a message with level *level* on the root logger. The other arguments are interpreted as for `debug()`.

PLEASE NOTE: The above module-level functions which delegate to the root logger should *not* be used in threads, in versions of Python earlier than 2.7.1 and 3.2, unless at least one handler has been added to the root logger *before* the threads are started. These convenience functions call `basicConfig()` to ensure that at least one handler is available; in earlier versions of Python, this can (under rare circumstances) lead to handlers being added multiple times to the root logger, which can in turn lead to multiple messages for the same event.

```
logging.disable(lvl)
```

Provides an overriding level *lvl* for all loggers which takes precedence over the logger's own level. When the need arises to temporarily throttle logging output down across the whole application, this function can be useful. Its effect is to disable all logging calls of severity *lvl* and below, so that if you call it with a value of INFO, then all INFO and DEBUG events would be discarded, whereas those of severity WARNING and above would be processed according to the logger's effective level. To undo the effect of a call to `logging.disable(lvl)`, call `logging.disable(logging.NOTSET)`.

`logging.addLevelName` (*lvl*, *levelName*)

Associates level *lvl* with text *levelName* in an internal dictionary, which is used to map numeric levels to a textual representation, for example when a `Formatter` formats a message. This function can also be used to define your own levels. The only constraints are that all levels used must be registered using this function, levels should be positive integers and they should increase in increasing order of severity.

NOTE: If you are thinking of defining your own levels, please see the section on *custom-levels*.

`logging.getLevelName` (*lvl*)

Returns the textual representation of logging level *lvl*. If the level is one of the predefined levels `CRITICAL`, `ERROR`, `WARNING`, `INFO` or `DEBUG` then you get the corresponding string. If you have associated levels with names using `addLevelName()` then the name you have associated with *lvl* is returned. If a numeric value corresponding to one of the defined levels is passed in, the corresponding string representation is returned. Otherwise, the string “Level %s” % *lvl* is returned.

`logging.makeLogRecord` (*attrdict*)

Creates and returns a new `LogRecord` instance whose attributes are defined by *attrdict*. This function is useful for taking a pickled `LogRecord` attribute dictionary, sent over a socket, and reconstituting it as a `LogRecord` instance at the receiving end.

`logging.basicConfig` (*[\*\*kwargs]*)

Does basic configuration for the logging system by creating a `StreamHandler` with a default `Formatter` and adding it to the root logger. The functions `debug()`, `info()`, `warning()`, `error()` and `critical()` will call `basicConfig()` automatically if no handlers are defined for the root logger.

This function does nothing if the root logger already has handlers configured for it. Changed in version 2.4: Formerly, `basicConfig()` did not take any keyword arguments. PLEASE NOTE: This function should be called from the main thread before other threads are started. In versions of Python prior to 2.7.1 and 3.2, if this function is called from multiple threads, it is possible (in rare circumstances) that a handler will be added to the root logger more than once, leading to unexpected results such as messages being duplicated in the log.

The following keyword arguments are supported.

Format	Description
<code>filename</code>	Specifies that a <code>FileHandler</code> be created, using the specified filename, rather than a <code>StreamHandler</code> .
<code>filemode</code>	Specifies the mode to open the file, if filename is specified (if filemode is unspecified, it defaults to 'a').
<code>format</code>	Use the specified format string for the handler.
<code>datefmt</code>	Use the specified date/time format.
<code>level</code>	Set the root logger level to the specified level.
<code>stream</code>	Use the specified stream to initialize the <code>StreamHandler</code> . Note that this argument is incompatible with 'filename' - if both are present, 'stream' is ignored.

`logging.shutdown` ()

Informs the logging system to perform an orderly shutdown by flushing and closing all handlers. This should be called at application exit and no further use of the logging system should be made after this call.

`logging.setLoggerClass` (*klass*)

Tells the logging system to use the class *klass* when instantiating a logger. The class should define `__init__()` such that only a name argument is required, and the `__init__()` should call `Logger.__init__()`. This function is typically called before any loggers are instantiated by applications which need to use custom logger behavior.

### 15.7.10 Integration with the warnings module

The `captureWarnings()` function can be used to integrate `logging` with the `warnings` module.

`logging.captureWarnings` (*capture*)

This function is used to turn the capture of warnings by logging on and off.

If *capture* is `True`, warnings issued by the `warnings` module will be redirected to the logging system. Specifically, a warning will be formatted using `warnings.formatwarning()` and the resulting string logged to a logger named `'py.warnings'` with a severity of `WARNING`.

If *capture* is `False`, the redirection of warnings to the logging system will stop, and warnings will be redirected to their original destinations (i.e. those in effect before `captureWarnings(True)` was called).

**See Also:**

**Module `logging.config`** Configuration API for the logging module.

**Module `logging.handlers`** Useful handlers included with the logging module.

**PEP 282 - A Logging System** The proposal which described this feature for inclusion in the Python standard library.

**Original Python logging package** This is the original source for the `logging` package. The version of the package available from this site is suitable for use with Python 1.5.2, 2.1.x and 2.2.x, which do not include the `logging` package in the standard library.

## 15.8 `logging.config` — Logging configuration

### Important

This page contains only reference information. For tutorials, please see

- *Basic Tutorial*
- *Advanced Tutorial*
- *Logging Cookbook*

This section describes the API for configuring the logging module.

### 15.8.1 Configuration functions

The following functions configure the logging module. They are located in the `logging.config` module. Their use is optional — you can configure the logging module using these functions or by making calls to the main API (defined in `logging` itself) and defining handlers which are declared either in `logging` or `logging.handlers`.

`logging.config.dictConfig` (*config*)

Takes the logging configuration from a dictionary. The contents of this dictionary are described in *Configuration dictionary schema* below.

If an error is encountered during configuration, this function will raise a `ValueError`, `TypeError`, `AttributeError` or `ImportError` with a suitably descriptive message. The following is a (possibly incomplete) list of conditions which will raise an error:

- A `level` which is not a string or which is a string not corresponding to an actual logging level.
- A `propagate` value which is not a boolean.
- An `id` which does not have a corresponding destination.
- A non-existent handler `id` found during an incremental call.
- An invalid logger name.

- Inability to resolve to an internal or external object.

Parsing is performed by the `DictConfigurator` class, whose constructor is passed the dictionary used for configuration, and has a `configure()` method. The `logging.config` module has a callable attribute `dictConfigClass` which is initially set to `DictConfigurator`. You can replace the value of `dictConfigClass` with a suitable implementation of your own.

`dictConfig()` calls `dictConfigClass` passing the specified dictionary, and then calls the `configure()` method on the returned object to put the configuration into effect:

```
def dictConfig(config):
    dictConfigClass(config).configure()
```

For example, a subclass of `DictConfigurator` could call `DictConfigurator.__init__()` in its own `__init__()`, then set up custom prefixes which would be usable in the subsequent `configure()` call. `dictConfigClass` would be bound to this new subclass, and then `dictConfig()` could be called exactly as in the default, uncustomized state.

New in version 2.7.

`logging.config.fileConfig(fname, defaults=None, disable_existing_loggers=True)`

Reads the logging configuration from a `configparser`-format file named `fname`. This function can be called several times from an application, allowing an end user to select from various pre-canned configurations (if the developer provides a mechanism to present the choices and load the chosen configuration).

#### Parameters

- **defaults** – Defaults to be passed to the `ConfigParser` can be specified in this argument.
- **disable\_existing\_loggers** – If specified as `False`, loggers which exist when this call is made are left alone. The default is `True` because this enables old behaviour in a backward-compatible way. This behaviour is to disable any existing loggers unless they or their ancestors are explicitly named in the logging configuration.

Changed in version 2.6: The `disable_existing_loggers` keyword argument was added. Previously, existing loggers were *always* disabled.

`logging.config.listen(port=DEFAULT_LOGGING_CONFIG_PORT)`

Starts up a socket server on the specified port, and listens for new configurations. If no port is specified, the module's default `DEFAULT_LOGGING_CONFIG_PORT` is used. Logging configurations will be sent as a file suitable for processing by `fileConfig()`. Returns a `Thread` instance on which you can call `start()` to start the server, and which you can `join()` when appropriate. To stop the server, call `stopListening()`.

To send a configuration to the socket, read in the configuration file and send it to the socket as a string of bytes preceded by a four-byte length string packed in binary using `struct.pack('>L', n)`.

---

**Note:** Because portions of the configuration are passed through `eval()`, use of this function may open its users to a security risk. While the function only binds to a socket on `localhost`, and so does not accept connections from remote machines, there are scenarios where untrusted code could be run under the account of the process which calls `listen()`. Specifically, if the process calling `listen()` runs on a multi-user machine where users cannot trust each other, then a malicious user could arrange to run essentially arbitrary code in a victim user's process, simply by connecting to the victim's `listen()` socket and sending a configuration which runs whatever code the attacker wants to have executed in the victim's process. This is especially easy to do if the default port is used, but not hard even if a different port is used).

---

`logging.config.stopListening()`

Stops the listening server which was created with a call to `listen()`. This is typically called before calling

`join()` on the return value from `listen()`.

## 15.8.2 Configuration dictionary schema

Describing a logging configuration requires listing the various objects to create and the connections between them; for example, you may create a handler named ‘console’ and then say that the logger named ‘startup’ will send its messages to the ‘console’ handler. These objects aren’t limited to those provided by the `logging` module because you might write your own formatter or handler class. The parameters to these classes may also need to include external objects such as `sys.stderr`. The syntax for describing these objects and connections is defined in *Object connections* below.

### Dictionary Schema Details

The dictionary passed to `dictConfig()` must contain the following keys:

- *version* - to be set to an integer value representing the schema version. The only valid value at present is 1, but having this key allows the schema to evolve while still preserving backwards compatibility.

All other keys are optional, but if present they will be interpreted as described below. In all cases below where a ‘configuring dict’ is mentioned, it will be checked for the special ‘()’ key to see if a custom instantiation is required. If so, the mechanism described in *User-defined objects* below is used to create an instance; otherwise, the context is used to determine what to instantiate.

- *formatters* - the corresponding value will be a dict in which each key is a formatter id and each value is a dict describing how to configure the corresponding Formatter instance.

The configuring dict is searched for keys `format` and `datefmt` (with defaults of `None`) and these are used to construct a `logging.Formatter` instance.

- *filters* - the corresponding value will be a dict in which each key is a filter id and each value is a dict describing how to configure the corresponding Filter instance.

The configuring dict is searched for the key `name` (defaulting to the empty string) and this is used to construct a `logging.Filter` instance.

- *handlers* - the corresponding value will be a dict in which each key is a handler id and each value is a dict describing how to configure the corresponding Handler instance.

The configuring dict is searched for the following keys:

- `class` (mandatory). This is the fully qualified name of the handler class.
- `level` (optional). The level of the handler.
- `formatter` (optional). The id of the formatter for this handler.
- `filters` (optional). A list of ids of the filters for this handler.

All *other* keys are passed through as keyword arguments to the handler’s constructor. For example, given the snippet:

```
handlers:
  console:
    class : logging.StreamHandler
    formatter: brief
    level  : INFO
    filters: [allow_foo]
    stream : ext://sys.stdout
  file:
```

```

class : logging.handlers.RotatingFileHandler
formatter: precise
filename: logconfig.log
maxBytes: 1024
backupCount: 3

```

the handler with id `console` is instantiated as a `logging.StreamHandler`, using `sys.stdout` as the underlying stream. The handler with id `file` is instantiated as a `logging.handlers.RotatingFileHandler` with the keyword arguments `filename='logconfig.log'`, `maxBytes=1024`, `backupCount=3`.

- *loggers* - the corresponding value will be a dict in which each key is a logger name and each value is a dict describing how to configure the corresponding Logger instance.

The configuring dict is searched for the following keys:

- `level` (optional). The level of the logger.
- `propagate` (optional). The propagation setting of the logger.
- `filters` (optional). A list of ids of the filters for this logger.
- `handlers` (optional). A list of ids of the handlers for this logger.

The specified loggers will be configured according to the level, propagation, filters and handlers specified.

- *root* - this will be the configuration for the root logger. Processing of the configuration will be as for any logger, except that the `propagate` setting will not be applicable.
- *incremental* - whether the configuration is to be interpreted as incremental to the existing configuration. This value defaults to `False`, which means that the specified configuration replaces the existing configuration with the same semantics as used by the existing `fileConfig()` API.

If the specified value is `True`, the configuration is processed as described in the section on *Incremental Configuration*.

- *disable\_existing\_loggers* - whether any existing loggers are to be disabled. This setting mirrors the parameter of the same name in `fileConfig()`. If absent, this parameter defaults to `True`. This value is ignored if *incremental* is `True`.

## Incremental Configuration

It is difficult to provide complete flexibility for incremental configuration. For example, because objects such as filters and formatters are anonymous, once a configuration is set up, it is not possible to refer to such anonymous objects when augmenting a configuration.

Furthermore, there is not a compelling case for arbitrarily altering the object graph of loggers, handlers, filters, formatters at run-time, once a configuration is set up; the verbosity of loggers and handlers can be controlled just by setting levels (and, in the case of loggers, propagation flags). Changing the object graph arbitrarily in a safe way is problematic in a multi-threaded environment; while not impossible, the benefits are not worth the complexity it adds to the implementation.

Thus, when the `incremental` key of a configuration dict is present and is `True`, the system will completely ignore any `formatters` and `filters` entries, and process only the `level` settings in the `handlers` entries, and the `level` and `propagate` settings in the `loggers` and `root` entries.

Using a value in the configuration dict lets configurations to be sent over the wire as pickled dicts to a socket listener. Thus, the logging verbosity of a long-running application can be altered over time with no need to stop and restart the application.

### Object connections

The schema describes a set of logging objects - loggers, handlers, formatters, filters - which are connected to each other in an object graph. Thus, the schema needs to represent connections between the objects. For example, say that, once configured, a particular logger has attached to it a particular handler. For the purposes of this discussion, we can say that the logger represents the source, and the handler the destination, of a connection between the two. Of course in the configured objects this is represented by the logger holding a reference to the handler. In the configuration dict, this is done by giving each destination object an id which identifies it unambiguously, and then using the id in the source object's configuration to indicate that a connection exists between the source and the destination object with that id.

So, for example, consider the following YAML snippet:

```
formatters:
  brief:
    # configuration for formatter with id 'brief' goes here
  precise:
    # configuration for formatter with id 'precise' goes here
handlers:
  h1: #This is an id
    # configuration of handler with id 'h1' goes here
    formatter: brief
  h2: #This is another id
    # configuration of handler with id 'h2' goes here
    formatter: precise
loggers:
  foo.bar.baz:
    # other configuration for logger 'foo.bar.baz'
    handlers: [h1, h2]
```

(Note: YAML used here because it's a little more readable than the equivalent Python source form for the dictionary.)

The ids for loggers are the logger names which would be used programmatically to obtain a reference to those loggers, e.g. `foo.bar.baz`. The ids for Formatters and Filters can be any string value (such as `brief`, `precise` above) and they are transient, in that they are only meaningful for processing the configuration dictionary and used to determine connections between objects, and are not persisted anywhere when the configuration call is complete.

The above snippet indicates that logger named `foo.bar.baz` should have two handlers attached to it, which are described by the handler ids `h1` and `h2`. The formatter for `h1` is that described by id `brief`, and the formatter for `h2` is that described by id `precise`.

### User-defined objects

The schema supports user-defined objects for handlers, filters and formatters. (Loggers do not need to have different types for different instances, so there is no support in this configuration schema for user-defined logger classes.)

Objects to be configured are described by dictionaries which detail their configuration. In some places, the logging system will be able to infer from the context how an object is to be instantiated, but when a user-defined object is to be instantiated, the system will not know how to do this. In order to provide complete flexibility for user-defined object instantiation, the user needs to provide a 'factory' - a callable which is called with a configuration dictionary and which returns the instantiated object. This is signalled by an absolute import path to the factory being made available under the special key '()''. Here's a concrete example:

```
formatters:
  brief:
    format: '%(message)s'
  default:
```

```

format: '%(asctime)s %(levelname)-8s %(name)-15s %(message)s'
datefmt: '%Y-%m-%d %H:%M:%S'
custom:
  (): my.package.customFormatterFactory
  bar: baz
  spam: 99.9
  answer: 42

```

The above YAML snippet defines three formatters. The first, with id `brief`, is a standard `logging.Formatter` instance with the specified format string. The second, with id `default`, has a longer format and also defines the time format explicitly, and will result in a `logging.Formatter` initialized with those two format strings. Shown in Python source form, the `brief` and `default` formatters have configuration sub-dictionaries:

```
{
  'format' : '%(message)s'
}
```

and:

```
{
  'format' : '%(asctime)s %(levelname)-8s %(name)-15s %(message)s',
  'datefmt' : '%Y-%m-%d %H:%M:%S'
}
```

respectively, and as these dictionaries do not contain the special key `'()'`, the instantiation is inferred from the context: as a result, standard `logging.Formatter` instances are created. The configuration sub-dictionary for the third formatter, with id `custom`, is:

```
{
  '()' : 'my.package.customFormatterFactory',
  'bar' : 'baz',
  'spam' : 99.9,
  'answer' : 42
}
```

and this contains the special key `'()'`, which means that user-defined instantiation is wanted. In this case, the specified factory callable will be used. If it is an actual callable it will be used directly - otherwise, if you specify a string (as in the example) the actual callable will be located using normal import mechanisms. The callable will be called with the **remaining** items in the configuration sub-dictionary as keyword arguments. In the above example, the formatter with id `custom` will be assumed to be returned by the call:

```
my.package.customFormatterFactory(bar='baz', spam=99.9, answer=42)
```

The key `'()'` has been used as the special key because it is not a valid keyword parameter name, and so will not clash with the names of the keyword arguments used in the call. The `'()'` also serves as a mnemonic that the corresponding value is a callable.

## Access to external objects

There are times where a configuration needs to refer to objects external to the configuration, for example `sys.stderr`. If the configuration dict is constructed using Python code, this is straightforward, but a problem arises when the configuration is provided via a text file (e.g. JSON, YAML). In a text file, there is no standard way to distinguish `sys.stderr` from the literal string `'sys.stderr'`. To facilitate this distinction, the configuration system looks for certain special prefixes in string values and treat them specially. For example, if the literal string `'ext://sys.stderr'` is provided as a value in the configuration, then the `ext://` will be stripped off and the remainder of the value processed using normal import mechanisms.

The handling of such prefixes is done in a way analogous to protocol handling: there is a generic mechanism to look for prefixes which match the regular expression `^(?P<prefix>[a-z]+) :// (?P<suffix>.*)$` whereby, if the `prefix` is recognised, the `suffix` is processed in a prefix-dependent manner and the result of the processing replaces the string value. If the prefix is not recognised, then the string value will be left as-is.

### Access to internal objects

As well as external objects, there is sometimes also a need to refer to objects in the configuration. This will be done implicitly by the configuration system for things that it knows about. For example, the string value `'DEBUG'` for a level in a logger or handler will automatically be converted to the value `logging.DEBUG`, and the `handlers`, `filters` and `formatter` entries will take an object id and resolve to the appropriate destination object.

However, a more generic mechanism is needed for user-defined objects which are not known to the `logging` module. For example, consider `logging.handlers.MemoryHandler`, which takes a `target` argument which is another handler to delegate to. Since the system already knows about this class, then in the configuration, the given `target` just needs to be the object id of the relevant target handler, and the system will resolve to the handler from the id. If, however, a user defines a `my.package.MyHandler` which has an `alternate` handler, the configuration system would not know that the `alternate` referred to a handler. To cater for this, a generic resolution system allows the user to specify:

```
handlers:
  file:
    # configuration of file handler goes here

  custom:
    (): my.package.MyHandler
    alternate: cfg://handlers.file
```

The literal string `'cfg://handlers.file'` will be resolved in an analogous way to strings with the `ext://` prefix, but looking in the configuration itself rather than the import namespace. The mechanism allows access by dot or by index, in a similar way to that provided by `str.format`. Thus, given the following snippet:

```
handlers:
  email:
    class: logging.handlers.SMTPHandler
    mailhost: localhost
    fromaddr: my_app@domain.tld
    toaddrs:
      - support_team@domain.tld
      - dev_team@domain.tld
    subject: Houston, we have a problem.
```

in the configuration, the string `'cfg://handlers'` would resolve to the dict with key `handlers`, the string `'cfg://handlers.email'` would resolve to the dict with key `email` in the `handlers` dict, and so on. The string `'cfg://handlers.email.toaddrs[1]'` would resolve to `'dev_team.domain.tld'` and the string `'cfg://handlers.email.toaddrs[0]'` would resolve to the value `'support_team@domain.tld'`. The subject value could be accessed using either `'cfg://handlers.email.subject'` or, equivalently, `'cfg://handlers.email[subject]'`. The latter form only needs to be used if the key contains spaces or non-alphanumeric characters. If an index value consists only of decimal digits, access will be attempted using the corresponding integer value, falling back to the string value if needed.

Given a string `cfg://handlers.myhandler.mykey.123`, this will resolve to `config_dict['handlers']['myhandler']['mykey']['123']`. If the string is specified as `cfg://handlers.myhandler.mykey[123]`, the system will attempt to retrieve the value from `config_dict['handlers']['myhandler']['mykey'][123]`, and fall back to `config_dict['handlers']['myhandler']['mykey']['123']` if that fails.

## Import resolution and custom importers

Import resolution, by default, uses the builtin `__import__()` function to do its importing. You may want to replace this with your own importing mechanism: if so, you can replace the `importer` attribute of the `DictConfigurator` or its superclass, the `BaseConfigurator` class. However, you need to be careful because of the way functions are accessed from classes via descriptors. If you are using a Python callable to do your imports, and you want to define it at class level rather than instance level, you need to wrap it with `staticmethod()`. For example:

```
from importlib import import_module
from logging.config import BaseConfigurator
```

```
BaseConfigurator.importer = staticmethod(import_module)
```

You don't need to wrap with `staticmethod()` if you're setting the import callable on a configurator *instance*.

## 15.8.3 Configuration file format

The configuration file format understood by `fileConfig()` is based on `configparser` functionality. The file must contain sections called `[loggers]`, `[handlers]` and `[formatters]` which identify by name the entities of each type which are defined in the file. For each such entity, there is a separate section which identifies how that entity is configured. Thus, for a logger named `log01` in the `[loggers]` section, the relevant configuration details are held in a section `[logger_log01]`. Similarly, a handler called `hand01` in the `[handlers]` section will have its configuration held in a section called `[handler_hand01]`, while a formatter called `form01` in the `[formatters]` section will have its configuration specified in a section called `[formatter_form01]`. The root logger configuration must be specified in a section called `[logger_root]`.

Examples of these sections in the file are given below.

```
[loggers]
keys=root,log02,log03,log04,log05,log06,log07
```

```
[handlers]
keys=hand01,hand02,hand03,hand04,hand05,hand06,hand07,hand08,hand09
```

```
[formatters]
keys=form01,form02,form03,form04,form05,form06,form07,form08,form09
```

The root logger must specify a level and a list of handlers. An example of a root logger section is given below.

```
[logger_root]
level=NOTSET
handlers=hand01
```

The `level` entry can be one of `DEBUG`, `INFO`, `WARNING`, `ERROR`, `CRITICAL` or `NOTSET`. For the root logger only, `NOTSET` means that all messages will be logged. Level values are `eval()` uated in the context of the `logging` package's namespace.

The `handlers` entry is a comma-separated list of handler names, which must appear in the `[handlers]` section. These names must appear in the `[handlers]` section and have corresponding sections in the configuration file.

For loggers other than the root logger, some additional information is required. This is illustrated by the following example.

```
[logger_parser]
level=DEBUG
handlers=hand01
```

```
propagate=1
qualname=compiler.parser
```

The `level` and `handlers` entries are interpreted as for the root logger, except that if a non-root logger's level is specified as `NOTSET`, the system consults loggers higher up the hierarchy to determine the effective level of the logger. The `propagate` entry is set to 1 to indicate that messages must propagate to handlers higher up the logger hierarchy from this logger, or 0 to indicate that messages are **not** propagated to handlers up the hierarchy. The `qualname` entry is the hierarchical channel name of the logger, that is to say the name used by the application to get the logger.

Sections which specify handler configuration are exemplified by the following.

```
[handler_hand01]
class=StreamHandler
level=NOTSET
formatter=form01
args=(sys.stdout,)
```

The `class` entry indicates the handler's class (as determined by `eval()` in the logging package's namespace). The `level` is interpreted as for loggers, and `NOTSET` is taken to mean 'log everything'. Changed in version 2.6: Added support for resolving the handler's class as a dotted module and class name. The `formatter` entry indicates the key name of the formatter for this handler. If blank, a default formatter (`logging._defaultFormatter`) is used. If a name is specified, it must appear in the `[formatters]` section and have a corresponding section in the configuration file.

The `args` entry, when `eval()` uated in the context of the logging package's namespace, is the list of arguments to the constructor for the handler class. Refer to the constructors for the relevant handlers, or to the examples below, to see how typical entries are constructed.

```
[handler_hand02]
class=FileHandler
level=DEBUG
formatter=form02
args=('python.log', 'w')
```

```
[handler_hand03]
class=handlers.SocketHandler
level=INFO
formatter=form03
args=('localhost', handlers.DEFAULT_TCP_LOGGING_PORT)
```

```
[handler_hand04]
class=handlers.DatagramHandler
level=WARN
formatter=form04
args=('localhost', handlers.DEFAULT_UDP_LOGGING_PORT)
```

```
[handler_hand05]
class=handlers.SysLogHandler
level=ERROR
formatter=form05
args=('localhost', handlers.SYSLOG_UDP_PORT), handlers.SysLogHandler.LOG_USER)
```

```
[handler_hand06]
class=handlers.NTEventLogHandler
level=CRITICAL
formatter=form06
args=('Python Application', '', 'Application')
```

```
[handler_hand07]
class=handlers.SMTPHandler
level=WARN
formatter=form07
args=('localhost', 'from@abc', ['user1@abc', 'user2@xyz'], 'Logger Subject')
```

```
[handler_hand08]
class=handlers.MemoryHandler
level=NOTSET
formatter=form08
target=
args=(10, ERROR)
```

```
[handler_hand09]
class=handlers.HTTPHandler
level=NOTSET
formatter=form09
args=('localhost:9022', '/log', 'GET')
```

Sections which specify formatter configuration are typified by the following.

```
[formatter_form01]
format=F1 %(asctime)s %(levelname)s %(message)s
datefmt=
class=logging.Formatter
```

The `format` entry is the overall format string, and the `datefmt` entry is the `strftime()`-compatible date/time format string. If empty, the package substitutes ISO8601 format date/times, which is almost equivalent to specifying the date format string `'%Y-%m-%d %H:%M:%S'`. The ISO8601 format also specifies milliseconds, which are appended to the result of using the above format string, with a comma separator. An example time in ISO8601 format is `2003-01-23 00:29:50,411`.

The `class` entry is optional. It indicates the name of the formatter's class (as a dotted module and class name.) This option is useful for instantiating a `Formatter` subclass. Subclasses of `Formatter` can present exception tracebacks in an expanded or condensed format.

---

**Note:** Due to the use of `eval()` as described above, there are potential security risks which result from using the `listen()` to send and receive configurations via sockets. The risks are limited to where multiple users with no mutual trust run code on the same machine; see the `listen()` documentation for more information.

---

**See Also:**

**Module `logging`** API reference for the logging module.

**Module `logging.handlers`** Useful handlers included with the logging module.

## 15.9 `logging.handlers` — Logging handlers

### Important

This page contains only reference information. For tutorials, please see

- *Basic Tutorial*
- *Advanced Tutorial*
- *Logging Cookbook*

The following useful handlers are provided in the package. Note that three of the handlers (`StreamHandler`, `FileHandler` and `NullHandler`) are actually defined in the `logging` module itself, but have been documented here along with the other handlers.

## 15.9.1 StreamHandler

The `StreamHandler` class, located in the core `logging` package, sends logging output to streams such as `sys.stdout`, `sys.stderr` or any file-like object (or, more precisely, any object which supports `write()` and `flush()` methods).

**class** `logging.StreamHandler` (*stream=None*)

Returns a new instance of the `StreamHandler` class. If *stream* is specified, the instance will use it for logging output; otherwise, `sys.stderr` will be used.

**emit** (*record*)

If a formatter is specified, it is used to format the record. The record is then written to the stream with a newline terminator. If exception information is present, it is formatted using `traceback.print_exception()` and appended to the stream.

**flush** ()

Flushes the stream by calling its `flush()` method. Note that the `close()` method is inherited from `Handler` and so does no output, so an explicit `flush()` call may be needed at times.

## 15.9.2 FileHandler

The `FileHandler` class, located in the core `logging` package, sends logging output to a disk file. It inherits the output functionality from `StreamHandler`.

**class** `logging.FileHandler` (*filename, mode='a', encoding=None, delay=False*)

Returns a new instance of the `FileHandler` class. The specified file is opened and used as the stream for logging. If *mode* is not specified, `'a'` is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely. Changed in version 2.6: *delay* was added.

**close** ()

Closes the file.

**emit** (*record*)

Outputs the record to the file.

## 15.9.3 NullHandler

New in version 2.7. The `NullHandler` class, located in the core `logging` package, does not do any formatting or output. It is essentially a 'no-op' handler for use by library developers.

**class** `logging.NullHandler`

Returns a new instance of the `NullHandler` class.

**emit** (*record*)

This method does nothing.

**handle** (*record*)

This method does nothing.

**createLock** ()

This method returns `None` for the lock, since there is no underlying I/O to which access needs to be serialized.

See *library-config* for more information on how to use `NullHandler`.

## 15.9.4 WatchedFileHandler

New in version 2.6. The `WatchedFileHandler` class, located in the `logging.handlers` module, is a `FileHandler` which watches the file it is logging to. If the file changes, it is closed and reopened using the file name.

A file change can happen because of usage of programs such as *newsyslog* and *logrotate* which perform log file rotation. This handler, intended for use under Unix/Linux, watches the file to see if it has changed since the last emit. (A file is deemed to have changed if its device or inode have changed.) If the file has changed, the old file stream is closed, and the file opened to get a new stream.

This handler is not appropriate for use under Windows, because under Windows open log files cannot be moved or renamed - logging opens the files with exclusive locks - and so there is no need for such a handler. Furthermore, `ST_INO` is not supported under Windows; `stat()` always returns zero for this value.

**class** `logging.handlers.WatchedFileHandler` (*filename*[, *mode*[, *encoding*[, *delay*]])

Returns a new instance of the `WatchedFileHandler` class. The specified file is opened and used as the stream for logging. If *mode* is not specified, 'a' is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely.

**emit** (*record*)

Outputs the record to the file, but first checks to see if the file has changed. If it has, the existing stream is flushed and closed and the file opened again, before outputting the record to the file.

## 15.9.5 RotatingFileHandler

The `RotatingFileHandler` class, located in the `logging.handlers` module, supports rotation of disk log files.

**class** `logging.handlers.RotatingFileHandler` (*filename*, *mode*='a', *maxBytes*=0, *backupCount*=0, *encoding*=`None`, *delay*=0)

Returns a new instance of the `RotatingFileHandler` class. The specified file is opened and used as the stream for logging. If *mode* is not specified, 'a' is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely.

You can use the *maxBytes* and *backupCount* values to allow the file to *rollover* at a predetermined size. When the size is about to be exceeded, the file is closed and a new file is silently opened for output. Rollover occurs whenever the current log file is nearly *maxBytes* in length; if *maxBytes* is zero, rollover never occurs. If *backupCount* is non-zero, the system will save old log files by appending the extensions '.1', '.2' etc., to the filename. For example, with a *backupCount* of 5 and a base file name of `app.log`, you would get `app.log`, `app.log.1`, `app.log.2`, up to `app.log.5`. The file being written to is always `app.log`. When this file is filled, it is closed and renamed to `app.log.1`, and if files `app.log.1`, `app.log.2`, etc. exist, then they are renamed to `app.log.2`, `app.log.3` etc. respectively. Changed in version 2.6: *delay* was added.

**doRollover** ()

Does a rollover, as described above.

**emit** (*record*)

Outputs the record to the file, catering for rollover as described previously.

## 15.9.6 TimedRotatingFileHandler

The `TimedRotatingFileHandler` class, located in the `logging.handlers` module, supports rotation of disk log files at certain timed intervals.

**class** `logging.handlers.TimedRotatingFileHandler` (*filename*, *when*='h', *interval*=1, *backupCount*=0, *encoding*=None, *delay*=False, *utc*=False)

Returns a new instance of the `TimedRotatingFileHandler` class. The specified file is opened and used as the stream for logging. On rotating it also sets the filename suffix. Rotating happens based on the product of *when* and *interval*.

You can use the *when* to specify the type of *interval*. The list of possible values is below. Note that they are not case sensitive.

Value	Type of interval
'S'	Seconds
'M'	Minutes
'H'	Hours
'D'	Days
'W'	Week day (0=Monday)
'midnight'	Roll over at midnight

The system will save old log files by appending extensions to the filename. The extensions are date-and-time based, using the strftime format `%Y-%m-%d_%H-%M-%S` or a leading portion thereof, depending on the rollover interval.

When computing the next rollover time for the first time (when the handler is created), the last modification time of an existing log file, or else the current time, is used to compute when the next rotation will occur.

If the *utc* argument is true, times in UTC will be used; otherwise local time is used.

If *backupCount* is nonzero, at most *backupCount* files will be kept, and if more would be created when rollover occurs, the oldest one is deleted. The deletion logic uses the interval to determine which files to delete, so changing the interval may leave old files lying around.

If *delay* is true, then file opening is deferred until the first call to `emit()`. Changed in version 2.6: *delay* and *utc* were added.

**doRollover** ()

Does a rollover, as described above.

**emit** (*record*)

Outputs the record to the file, catering for rollover as described above.

## 15.9.7 SocketHandler

The `SocketHandler` class, located in the `logging.handlers` module, sends logging output to a network socket. The base class uses a TCP socket.

**class** `logging.handlers.SocketHandler` (*host*, *port*)

Returns a new instance of the `SocketHandler` class intended to communicate with a remote machine whose address is given by *host* and *port*.

**close ()**

Closes the socket.

**emit ()**

Pickles the record's attribute dictionary and writes it to the socket in binary format. If there is an error with the socket, silently drops the packet. If the connection was previously lost, re-establishes the connection. To unpickle the record at the receiving end into a `LogRecord`, use the `makeLogRecord ()` function.

**handleError ()**

Handles an error which has occurred during `emit ()`. The most likely cause is a lost connection. Closes the socket so that we can retry on the next event.

**makeSocket ()**

This is a factory method which allows subclasses to define the precise type of socket they want. The default implementation creates a TCP socket (`socket.SOCK_STREAM`).

**makePickle (record)**

Pickles the record's attribute dictionary in binary format with a length prefix, and returns it ready for transmission across the socket.

Note that pickles aren't completely secure. If you are concerned about security, you may want to override this method to implement a more secure mechanism. For example, you can sign pickles using HMAC and then verify them on the receiving end, or alternatively you can disable unpickling of global objects on the receiving end.

**send (packet)**

Send a pickled string *packet* to the socket. This function allows for partial sends which can happen when the network is busy.

**createSocket ()**

Tries to create a socket; on failure, uses an exponential back-off algorithm. On initial failure, the handler will drop the message it was trying to send. When subsequent messages are handled by the same instance, it will not try connecting until some time has passed. The default parameters are such that the initial delay is one second, and if after that delay the connection still can't be made, the handler will double the delay each time up to a maximum of 30 seconds.

This behaviour is controlled by the following handler attributes:

- `retryStart` (initial delay, defaulting to 1.0 seconds).
- `retryFactor` (multiplier, defaulting to 2.0).
- `retryMax` (maximum delay, defaulting to 30.0 seconds).

This means that if the remote listener starts up *after* the handler has been used, you could lose messages (since the handler won't even attempt a connection until the delay has elapsed, but just silently drop messages during the delay period).

## 15.9.8 DatagramHandler

The `DatagramHandler` class, located in the `logging.handlers` module, inherits from `SocketHandler` to support sending logging messages over UDP sockets.

**class logging.handlers.DatagramHandler (host, port)**

Returns a new instance of the `DatagramHandler` class intended to communicate with a remote machine whose address is given by *host* and *port*.

**emit ()**

Pickles the record's attribute dictionary and writes it to the socket in binary format. If there is an error with

the socket, silently drops the packet. To unpickle the record at the receiving end into a `LogRecord`, use the `makeLogRecord()` function.

**makeSocket()**

The factory method of `SocketHandler` is here overridden to create a UDP socket (`socket.SOCK_DGRAM`).

**send(s)**

Send a pickled string to a socket.

## 15.9.9 SysLogHandler

The `SysLogHandler` class, located in the `logging.handlers` module, supports sending logging messages to a remote or local Unix syslog.

**class** `logging.handlers.SysLogHandler` (*address*=(`'localhost'`, `SYSLOG_UDP_PORT`), *facility*=`LOG_USER`, *socktype*=`socket.SOCK_DGRAM`)

Returns a new instance of the `SysLogHandler` class intended to communicate with a remote Unix machine whose address is given by *address* in the form of a (`host`, `port`) tuple. If *address* is not specified, (`'localhost'`, `514`) is used. The address is used to open a socket. An alternative to providing a (`host`, `port`) tuple is providing an address as a string, for example `'/dev/log'`. In this case, a Unix domain socket is used to send the message to the syslog. If *facility* is not specified, `LOG_USER` is used. The type of socket opened depends on the *socktype* argument, which defaults to `socket.SOCK_DGRAM` and thus opens a UDP socket. To open a TCP socket (for use with the newer syslog daemons such as `rsyslog`), specify a value of `socket.SOCK_STREAM`.

Note that if your server is not listening on UDP port 514, `SysLogHandler` may appear not to work. In that case, check what address you should be using for a domain socket - it's system dependent. For example, on Linux it's usually `'/dev/log'` but on OS/X it's `'/var/run/syslog'`. You'll need to check your platform and use the appropriate address (you may need to do this check at runtime if your application needs to run on several platforms). On Windows, you pretty much have to use the UDP option. Changed in version 2.7: *socktype* was added.

**close()**

Closes the socket to the remote host.

**emit(record)**

The record is formatted, and then sent to the syslog server. If exception information is present, it is *not* sent to the server.

**encodePriority(facility, priority)**

Encodes the facility and priority into an integer. You can pass in strings or integers - if strings are passed, internal mapping dictionaries are used to convert them to integers.

The symbolic `LOG_` values are defined in `SysLogHandler` and mirror the values defined in the `sys/syslog.h` header file.

**Priorities**

Name (string)	Symbolic value
alert	LOG_ALERT
crit or critical	LOG_CRIT
debug	LOG_DEBUG
emerg or panic	LOG_EMERG
err or error	LOG_ERR
info	LOG_INFO
notice	LOG_NOTICE
warn or warning	LOG_WARNING

**Facilities**

Name (string)	Symbolic value
auth	LOG_AUTH
authpriv	LOG_AUTHPRIV
cron	LOG_CRON
daemon	LOG_DAEMON
ftp	LOG_FTP
kern	LOG_KERN
lpr	LOG_LPR
mail	LOG_MAIL
news	LOG_NEWS
syslog	LOG_SYSLOG
user	LOG_USER
uucp	LOG_UUCP
local0	LOG_LOCAL0
local1	LOG_LOCAL1
local2	LOG_LOCAL2
local3	LOG_LOCAL3
local4	LOG_LOCAL4
local5	LOG_LOCAL5
local6	LOG_LOCAL6
local7	LOG_LOCAL7

**mapPriority** (*levelname*)

Maps a logging level name to a syslog priority name. You may need to override this if you are using custom levels, or if the default algorithm is not suitable for your needs. The default algorithm maps `DEBUG`, `INFO`, `WARNING`, `ERROR` and `CRITICAL` to the equivalent syslog names, and all other level names to 'warning'.

### 15.9.10 NTEventLogHandler

The `NTEventLogHandler` class, located in the `logging.handlers` module, supports sending logging messages to a local Windows NT, Windows 2000 or Windows XP event log. Before you can use it, you need Mark Hammond's Win32 extensions for Python installed.

**class** `logging.handlers.NTEventLogHandler` (*appname*, *dllname=None*, *logtype='Application'*)

Returns a new instance of the `NTEventLogHandler` class. The *appname* is used to define the application name as it appears in the event log. An appropriate registry entry is created using this name. The *dllname* should give the fully qualified pathname of a `.dll` or `.exe` which contains message definitions to hold in the log (if not specified, `'win32service.pyd'` is used - this is installed with the Win32 extensions and contains some basic placeholder message definitions. Note that use of these placeholders will make your event logs big, as the entire message source is held in the log. If you want slimmer logs, you have to pass in the name of your own `.dll` or `.exe` which contains the message definitions you want to use in the event log). The *logtype* is one of `'Application'`, `'System'` or `'Security'`, and defaults to `'Application'`.

**close** ()

At this point, you can remove the application name from the registry as a source of event log entries. However, if you do this, you will not be able to see the events as you intended in the Event Log Viewer - it needs to be able to access the registry to get the `.dll` name. The current version does not do this.

**emit** (*record*)

Determines the message ID, event category and event type, and then logs the message in the NT event log.

**getEventCategory** (*record*)

Returns the event category for the record. Override this if you want to specify your own categories. This version returns 0.

**getEventType** (*record*)

Returns the event type for the record. Override this if you want to specify your own types. This version does a mapping using the handler's `typemap` attribute, which is set up in `__init__()` to a dictionary which contains mappings for `DEBUG`, `INFO`, `WARNING`, `ERROR` and `CRITICAL`. If you are using your own levels, you will either need to override this method or place a suitable dictionary in the handler's `typemap` attribute.

**getMessageID** (*record*)

Returns the message ID for the record. If you are using your own messages, you could do this by having the `msg` passed to the logger being an ID rather than a format string. Then, in here, you could use a dictionary lookup to get the message ID. This version returns 1, which is the base message ID in `win32service.pyd`.

### 15.9.11 SMTPHandler

The `SMTPHandler` class, located in the `logging.handlers` module, supports sending logging messages to an email address via SMTP.

**class** `logging.handlers.SMTPHandler` (*mailhost, fromaddr, toaddrs, subject, credentials=None, secure=None*)

Returns a new instance of the `SMTPHandler` class. The instance is initialized with the from and to addresses and subject line of the email. The `toaddrs` should be a list of strings. To specify a non-standard SMTP port, use the (host, port) tuple format for the `mailhost` argument. If you use a string, the standard SMTP port is used. If your SMTP server requires authentication, you can specify a (username, password) tuple for the `credentials` argument.

To specify the use of a secure protocol (TLS), pass in a tuple to the `secure` argument. This will only be used when authentication credentials are supplied. The tuple should be either an empty tuple, or a single-value tuple with the name of a keyfile, or a 2-value tuple with the names of the keyfile and certificate file. (This tuple is passed to the `smtplib.SMTP.starttls()` method.) Changed in version 2.6: `credentials` was added. Changed in version 2.7: `secure` was added.

**emit** (*record*)

Formats the record and sends it to the specified addressees.

**getSubject** (*record*)

If you want to specify a subject line which is record-dependent, override this method.

### 15.9.12 MemoryHandler

The `MemoryHandler` class, located in the `logging.handlers` module, supports buffering of logging records in memory, periodically flushing them to a `target` handler. Flushing occurs whenever the buffer is full, or when an event of a certain severity or greater is seen.

`MemoryHandler` is a subclass of the more general `BufferingHandler`, which is an abstract class. This buffers logging records in memory. Whenever each record is added to the buffer, a check is made by calling `shouldFlush()` to see if the buffer should be flushed. If it should, then `flush()` is expected to do the flushing.

**class** `logging.handlers.BufferingHandler` (*capacity*)

Initializes the handler with a buffer of the specified capacity.

**emit** (*record*)

Appends the record to the buffer. If `shouldFlush()` returns true, calls `flush()` to process the buffer.

**flush** ()

You can override this to implement custom flushing behavior. This version just zaps the buffer to empty.

**shouldFlush** (*record*)

Returns true if the buffer is up to capacity. This method can be overridden to implement custom flushing strategies.

**class** logging.handlers.**MemoryHandler** (*capacity, flushLevel=ERROR, target=None*)

Returns a new instance of the `MemoryHandler` class. The instance is initialized with a buffer size of *capacity*. If *flushLevel* is not specified, `ERROR` is used. If no *target* is specified, the target will need to be set using `setTarget()` before this handler does anything useful.

**close** ()

Calls `flush()`, sets the target to `None` and clears the buffer.

**flush** ()

For a `MemoryHandler`, flushing means just sending the buffered records to the target, if there is one. The buffer is also cleared when this happens. Override if you want different behavior.

**setTarget** (*target*)

Sets the target handler for this handler.

**shouldFlush** (*record*)

Checks for buffer full or a record at the *flushLevel* or higher.

### 15.9.13 HTTPHandler

The `HTTPHandler` class, located in the `logging.handlers` module, supports sending logging messages to a Web server, using either GET or POST semantics.

**class** logging.handlers.**HTTPHandler** (*host, url, method='GET'*)

Returns a new instance of the `HTTPHandler` class. The *host* can be of the form `host:port`, should you need to use a specific port number. If no *method* is specified, GET is used.

**emit** (*record*)

Sends the record to the Web server as a percent-encoded dictionary.

**See Also:**

**Module logging** API reference for the logging module.

**Module logging.config** Configuration API for the logging module.

## 15.10 getpass — Portable password input

The `getpass` module provides two functions:

`getpass.getpass` (*[prompt[, stream]]*)

Prompt the user for a password without echoing. The user is prompted using the string *prompt*, which defaults to `'Password: '`. On Unix, the prompt is written to the file-like object *stream*. *stream* defaults to the controlling terminal (`/dev/tty`) or if that is unavailable to `sys.stderr` (this argument is ignored on Windows).

If echo free input is unavailable `getpass()` falls back to printing a warning message to *stream* and reading from `sys.stdin` and issuing a `GetPassWarning`.

Availability: Macintosh, Unix, Windows. Changed in version 2.5: The *stream* parameter was added. Changed in version 2.6: On Unix it defaults to using `/dev/tty` before falling back to `sys.stdin` and `sys.stderr`.

---

**Note:** If you call `getpass` from within IDLE, the input may be done in the terminal you launched IDLE from rather than the idle window itself.

---

**exception** `getpass.GetPassWarning`

A `UserWarning` subclass issued when password input may be echoed.

`getpass.getuser()`

Return the “login name” of the user. Availability: Unix, Windows.

This function checks the environment variables `LOGNAME`,

`USER`, `LNAME` and `USERNAME`, in order, and returns the value of the first one which is set to a non-empty string. If none are set, the login name from the password database is returned on systems which support the `pwd` module, otherwise, an exception is raised.

## 15.11 `curses` — Terminal handling for character-cell displays

*Platforms:* Unix

Changed in version 1.6: Added support for the `ncurses` library and converted to a package. The `curses` module provides an interface to the `curses` library, the de-facto standard for portable advanced terminal handling.

While `curses` is most widely used in the Unix environment, versions are available for DOS, OS/2, and possibly other systems as well. This extension module is designed to match the API of `ncurses`, an open-source `curses` library hosted on Linux and the BSD variants of Unix.

---

**Note:** Since version 5.4, the `ncurses` library decides how to interpret non-ASCII data using the `nl_langinfo` function. That means that you have to call `locale.setlocale()` in the application and encode Unicode strings using one of the system’s available encodings. This example uses the system’s default encoding:

**import** `locale`

```
locale.setlocale(locale.LC_ALL, '')
code = locale.getpreferredencoding()
```

Then use `code` as the encoding for `str.encode()` calls.

---

**See Also:**

**Module** `curses.ascii` Utilities for working with ASCII characters, regardless of your locale settings.

**Module** `curses.panel` A panel stack extension that adds depth to `curses` windows.

**Module** `curses.textpad` Editable text widget for `curses` supporting **Emacs**-like bindings.

***curses-howto*** Tutorial material on using `curses` with Python, by Andrew Kuchling and Eric Raymond.

The `Demo/curses/` directory in the Python source distribution contains some example programs using the `curses` bindings provided by this module.

### 15.11.1 Functions

The module `curses` defines the following exception:

**exception** `curses.error`

Exception raised when a `curses` library function returns an error.

---

**Note:** Whenever `x` or `y` arguments to a function or a method are optional, they default to the current cursor location. Whenever `attr` is optional, it defaults to `A_NORMAL`.

---

The module `curses` defines the following functions:

`curses.baudrate()`

Return the output speed of the terminal in bits per second. On software terminal emulators it will have a fixed high value. Included for historical reasons; in former times, it was used to write output loops for time delays and occasionally to change interfaces depending on the line speed.

`curses.beep()`

Emit a short attention sound.

`curses.can_change_color()`

Return `True` or `False`, depending on whether the programmer can change the colors displayed by the terminal.

`curses.cbreak()`

Enter cbreak mode. In cbreak mode (sometimes called “rare” mode) normal tty line buffering is turned off and characters are available to be read one by one. However, unlike raw mode, special characters (interrupt, quit, suspend, and flow control) retain their effects on the tty driver and calling program. Calling first `raw()` then `cbreak()` leaves the terminal in cbreak mode.

`curses.color_content(color_number)`

Return the intensity of the red, green, and blue (RGB) components in the color *color\_number*, which must be between 0 and `COLORS`. A 3-tuple is returned, containing the R,G,B values for the given color, which will be between 0 (no component) and 1000 (maximum amount of component).

`curses.color_pair(color_number)`

Return the attribute value for displaying text in the specified color. This attribute value can be combined with `A_STANDOUT`, `A_REVERSE`, and the other `A_*` attributes. `pair_number()` is the counterpart to this function.

`curses.curs_set(visibility)`

Set the cursor state. *visibility* can be set to 0, 1, or 2, for invisible, normal, or very visible. If the terminal supports the visibility requested, the previous cursor state is returned; otherwise, an exception is raised. On many terminals, the “visible” mode is an underline cursor and the “very visible” mode is a block cursor.

`curses.def_prog_mode()`

Save the current terminal mode as the “program” mode, the mode when the running program is using curses. (Its counterpart is the “shell” mode, for when the program is not in curses.) Subsequent calls to `reset_prog_mode()` will restore this mode.

`curses.def_shell_mode()`

Save the current terminal mode as the “shell” mode, the mode when the running program is not using curses. (Its counterpart is the “program” mode, when the program is using curses capabilities.) Subsequent calls to `reset_shell_mode()` will restore this mode.

`curses.delay_output(ms)`

Insert an *ms* millisecond pause in output.

`curses.doupdate()`

Update the physical screen. The curses library keeps two data structures, one representing the current physical screen contents and a virtual screen representing the desired next state. The `doupdate()` ground updates the physical screen to match the virtual screen.

The virtual screen may be updated by a `noutrefresh()` call after write operations such as `addstr()` have been performed on a window. The normal `refresh()` call is simply `noutrefresh()` followed by `doupdate()`; if you have to update multiple windows, you can speed performance and perhaps reduce screen flicker by issuing `noutrefresh()` calls on all windows, followed by a single `doupdate()`.

`curses.echo()`

Enter echo mode. In echo mode, each character input is echoed to the screen as it is entered.

`curses.endwin()`

De-initialize the library, and return terminal to normal status.

`curses.erasechar()`

Return the user's current erase character. Under Unix operating systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

`curses.filter()`

The `filter()` routine, if used, must be called before `initscr()` is called. The effect is that, during those calls, `LINES` is set to 1; the capabilities `clear`, `cup`, `cud`, `cud1`, `cuu1`, `cuu`, `vpa` are disabled; and the home string is set to the value of `cr`. The effect is that the cursor is confined to the current line, and so are screen updates. This may be used for enabling character-at-a-time line editing without touching the rest of the screen.

`curses.flash()`

Flash the screen. That is, change it to reverse-video and then change it back in a short interval. Some people prefer such as 'visible bell' to the audible attention signal produced by `beep()`.

`curses.flushinp()`

Flush all input buffers. This throws away any typeahead that has been typed by the user and has not yet been processed by the program.

`curses.getmouse()`

After `getch()` returns `KEY_MOUSE` to signal a mouse event, this method should be called to retrieve the queued mouse event, represented as a 5-tuple (`id`, `x`, `y`, `z`, `bstate`). `id` is an ID value used to distinguish multiple devices, and `x`, `y`, `z` are the event's coordinates. (`z` is currently unused.) `bstate` is an integer value whose bits will be set to indicate the type of event, and will be the bitwise OR of one or more of the following constants, where `n` is the button number from 1 to 4: `BUTTONn_PRESSED`, `BUTTONn_RELEASED`, `BUTTONn_CLICKED`, `BUTTONn_DOUBLE_CLICKED`, `BUTTONn_TRIPLE_CLICKED`, `BUTTON_SHIFT`, `BUTTON_CTRL`, `BUTTON_ALT`.

`curses.getsyx()`

Return the current coordinates of the virtual screen cursor in `y` and `x`. If `leaveok` is currently true, then -1,-1 is returned.

`curses.getwin(file)`

Read window related data stored in the file by an earlier `putwin()` call. The routine then creates and initializes a new window using that data, returning the new window object.

`curses.has_colors()`

Return True if the terminal can display colors; otherwise, return False.

`curses.has_ic()`

Return True if the terminal has insert- and delete-character capabilities. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

`curses.has_il()`

Return True if the terminal has insert- and delete-line capabilities, or can simulate them using scrolling regions. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

`curses.has_key(ch)`

Take a key value `ch`, and return True if the current terminal type recognizes a key with that value.

`curses.halfdelay(tenths)`

Used for half-delay mode, which is similar to `cbreak` mode in that characters typed by the user are immediately available to the program. However, after blocking for `tenths` tenths of seconds, an exception is raised if nothing has been typed. The value of `tenths` must be a number between 1 and 255. Use `nocbreak()` to leave half-delay mode.

`curses.init_color(color_number, r, g, b)`

Change the definition of a color, taking the number of the color to be changed followed by three RGB values (for the amounts of red, green, and blue components). The value of `color_number` must be between 0 and `COLORS`. Each of `r`, `g`, `b`, must be a value between 0 and 1000. When `init_color()` is used, all occurrences of that

color on the screen immediately change to the new definition. This function is a no-op on most terminals; it is active only if `can_change_color()` returns 1.

`curses.init_pair(pair_number, fg, bg)`

Change the definition of a color-pair. It takes three arguments: the number of the color-pair to be changed, the foreground color number, and the background color number. The value of *pair\_number* must be between 1 and `COLOR_PAIRS - 1` (the 0 color pair is wired to white on black and cannot be changed). The value of *fg* and *bg* arguments must be between 0 and `COLORS`. If the color-pair was previously initialized, the screen is refreshed and all occurrences of that color-pair are changed to the new definition.

`curses.initscr()`

Initialize the library. Return a `WindowObject` which represents the whole screen.

---

**Note:** If there is an error opening the terminal, the underlying curses library may cause the interpreter to exit.

---

`curses.is_term_resized(nlines, ncols)`

Return `True` if `resize_term()` would modify the window structure, `False` otherwise.

`curses.isendwin()`

Return `True` if `endwin()` has been called (that is, the curses library has been deinitialized).

`curses.keyname(k)`

Return the name of the key numbered *k*. The name of a key generating printable ASCII character is the key's character. The name of a control-key combination is a two-character string consisting of a caret followed by the corresponding printable ASCII character. The name of an alt-key combination (128-255) is a string consisting of the prefix 'M-' followed by the name of the corresponding ASCII character.

`curses.killchar()`

Return the user's current line kill character. Under Unix operating systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

`curses.longname()`

Return a string containing the terminfo long name field describing the current terminal. The maximum length of a verbose description is 128 characters. It is defined only after the call to `initscr()`.

`curses.meta(yes)`

If *yes* is 1, allow 8-bit characters to be input. If *yes* is 0, allow only 7-bit chars.

`curses.mouseinterval(interval)`

Set the maximum time in milliseconds that can elapse between press and release events in order for them to be recognized as a click, and return the previous interval value. The default value is 200 msec, or one fifth of a second.

`curses.mousemask(mousemask)`

Set the mouse events to be reported, and return a tuple (*availmask*, *oldmask*). *availmask* indicates which of the specified mouse events can be reported; on complete failure it returns 0. *oldmask* is the previous value of the given window's mouse event mask. If this function is never called, no mouse events are ever reported.

`curses.napms(ms)`

Sleep for *ms* milliseconds.

`curses.newpad(nlines, ncols)`

Create and return a pointer to a new pad data structure with the given number of lines and columns. A pad is returned as a window object.

A pad is like a window, except that it is not restricted by the screen size, and is not necessarily associated with a particular part of the screen. Pads can be used when a large window is needed, and only a part of the window will be on the screen at one time. Automatic refreshes of pads (such as from scrolling or echoing of input) do not occur. The `refresh()` and `noutrefresh()` methods of a pad require 6 arguments to specify the part

of the pad to be displayed and the location on the screen to be used for the display. The arguments are *pminrow*, *pmincol*, *sminrow*, *smincol*, *smaxrow*, *smaxcol*; the *p* arguments refer to the upper left corner of the pad region to be displayed and the *s* arguments define a clipping box on the screen within which the pad region is to be displayed.

`curses.newwin(begin_y, begin_x)`

`curses.newwin(nlines, ncols, begin_y, begin_x)`

Return a new window, whose left-upper corner is at `(begin_y, begin_x)`, and whose height/width is `nlines/ncols`.

By default, the window will extend from the specified position to the lower right corner of the screen.

`curses.nl()`

Enter newline mode. This mode translates the return key into newline on input, and translates newline into return and line-feed on output. Newline mode is initially on.

`curses.nocbreak()`

Leave cbreak mode. Return to normal “cooked” mode with line buffering.

`curses.noecho()`

Leave echo mode. Echoing of input characters is turned off.

`curses.nonl()`

Leave newline mode. Disable translation of return into newline on input, and disable low-level translation of newline into newline/return on output (but this does not change the behavior of `addch('\n')`, which always does the equivalent of return and line feed on the virtual screen). With translation off, curses can sometimes speed up vertical motion a little; also, it will be able to detect the return key on input.

`curses.noqiflush()`

When the `noqiflush()` routine is used, normal flush of input and output queues associated with the INTR, QUIT and SUSP characters will not be done. You may want to call `noqiflush()` in a signal handler if you want output to continue as though the interrupt had not occurred, after the handler exits.

`curses.noraw()`

Leave raw mode. Return to normal “cooked” mode with line buffering.

`curses.pair_content(pair_number)`

Return a tuple `(fg, bg)` containing the colors for the requested color pair. The value of `pair_number` must be between 1 and `COLOR_PAIRS - 1`.

`curses.pair_number(attr)`

Return the number of the color-pair set by the attribute value `attr`. `color_pair()` is the counterpart to this function.

`curses.putp(string)`

Equivalent to `tputs(str, 1, putchar)`; emit the value of a specified terminfo capability for the current terminal. Note that the output of `putp()` always goes to standard output.

`curses.qiflush([flag])`

If `flag` is `False`, the effect is the same as calling `noqiflush()`. If `flag` is `True`, or no argument is provided, the queues will be flushed when these control characters are read.

`curses.raw()`

Enter raw mode. In raw mode, normal line buffering and processing of interrupt, quit, suspend, and flow control keys are turned off; characters are presented to curses input functions one by one.

`curses.reset_prog_mode()`

Restore the terminal to “program” mode, as previously saved by `def_prog_mode()`.

`curses.reset_shell_mode()`

Restore the terminal to “shell” mode, as previously saved by `def_shell_mode()`.

`curses.resetty()`

Restore the state of the terminal modes to what it was at the last call to `savetty()`.

`curses.resize_term(nlines, ncols)`

Backend function used by `resizeterm()`, performing most of the work; when resizing the windows, `resize_term()` blank-fills the areas that are extended. The calling application should fill in these areas with appropriate data. The `resize_term()` function attempts to resize all windows. However, due to the calling convention of pads, it is not possible to resize these without additional interaction with the application.

`curses.resizeterm(nlines, ncols)`

Resize the standard and current windows to the specified dimensions, and adjusts other bookkeeping data used by the curses library that record the window dimensions (in particular the SIGWINCH handler).

`curses.savetty()`

Save the current state of the terminal modes in a buffer, usable by `resetty()`.

`curses.setsyx(y, x)`

Set the virtual screen cursor to `y, x`. If `y` and `x` are both -1, then leaveok is set.

`curses.setupterm([termstr, fd])`

Initialize the terminal. `termstr` is a string giving the terminal name; if omitted, the value of the TERM environment variable will be used. `fd` is the file descriptor to which any initialization sequences will be sent; if not supplied, the file descriptor for `sys.stdout` will be used.

`curses.start_color()`

Must be called if the programmer wants to use colors, and before any other color manipulation routine is called. It is good practice to call this routine right after `initscr()`.

`start_color()` initializes eight basic colors (black, red, green, yellow, blue, magenta, cyan, and white), and two global variables in the `curses` module, `COLORS` and `COLOR_PAIRS`, containing the maximum number of colors and color-pairs the terminal can support. It also restores the colors on the terminal to the values they had when the terminal was just turned on.

`curses.termattrs()`

Return a logical OR of all video attributes supported by the terminal. This information is useful when a curses program needs complete control over the appearance of the screen.

`curses.termname()`

Return the value of the environment variable TERM, truncated to 14 characters.

`curses.tigetflag(capname)`

Return the value of the Boolean capability corresponding to the terminfo capability name `capname`. The value -1 is returned if `capname` is not a Boolean capability, or 0 if it is canceled or absent from the terminal description.

`curses.tigetnum(capname)`

Return the value of the numeric capability corresponding to the terminfo capability name `capname`. The value -2 is returned if `capname` is not a numeric capability, or -1 if it is canceled or absent from the terminal description.

`curses.tigetstr(capname)`

Return the value of the string capability corresponding to the terminfo capability name `capname`. None is returned if `capname` is not a string capability, or is canceled or absent from the terminal description.

`curses.tparm(str[, ...])`

Instantiate the string `str` with the supplied parameters, where `str` should be a parameterized string obtained from the terminfo database. E.g. `tparm(tigetstr("cup"), 5, 3)` could result in `'\033[6;4H'`, the exact result depending on terminal type.

`curses.typeahead(fd)`

Specify that the file descriptor *fd* be used for typeahead checking. If *fd* is `-1`, then no typeahead checking is done.

The curses library does “line-breakout optimization” by looking for typeahead periodically while updating the screen. If input is found, and it is coming from a tty, the current update is postponed until `refresh` or `doupdate` is called again, allowing faster response to commands typed in advance. This function allows specifying a different file descriptor for typeahead checking.

`curses.unctrl(ch)`

Return a string which is a printable representation of the character *ch*. Control characters are displayed as a caret followed by the character, for example as `^C`. Printing characters are left as they are.

`curses.ungetch(ch)`

Push *ch* so the next `getch()` will return it.

---

**Note:** Only one *ch* can be pushed before `getch()` is called.

---

`curses.ungetmouse(id, x, y, z, bstate)`

Push a `KEY_MOUSE` event onto the input queue, associating the given state data with it.

`curses.use_env(flag)`

If used, this function should be called before `initscr()` or `newterm` are called. When *flag* is `False`, the values of lines and columns specified in the terminfo database will be used, even if environment variables `LINES` and `COLUMNS` (used by default) are set, or if curses is running in a window (in which case default behavior would be to use the window size if

`LINES` and `COLUMNS` are not set).

`curses.use_default_colors()`

Allow use of default values for colors on terminals supporting this feature. Use this to support transparency in your application. The default color is assigned to the color number `-1`. After calling this function, `init_pair(x, curses.COLOR_RED, -1)` initializes, for instance, color pair *x* to a red foreground color on the default background.

`curses.wrapper(func, ...)`

Initialize curses and call another callable object, *func*, which should be the rest of your curses-using application. If the application raises an exception, this function will restore the terminal to a sane state before re-raising the exception and generating a traceback. The callable object *func* is then passed the main window `'stdscr'` as its first argument, followed by any other arguments passed to `wrapper()`. Before calling *func*, `wrapper()` turns on `cbreak` mode, turns off `echo`, enables the terminal keypad, and initializes colors if the terminal has color support. On exit (whether normally or by exception) it restores `cooked` mode, turns on `echo`, and disables the terminal keypad.

### 15.11.2 Window Objects

Window objects, as returned by `initscr()` and `newwin()` above, have the following methods:

`window.addch(ch[, attr])`

`window.addch(y, x, ch[, attr])`

---

**Note:** A *character* means a C character (an ASCII code), rather than a Python character (a string of length 1). (This note is true whenever the documentation mentions a character.) The built-in `ord()` is handy for conveying strings to codes.

---

Paint character *ch* at (*y*, *x*) with attributes *attr*, overwriting any character previously painter at that location. By default, the character position and attributes are the current settings for the window object.

`window.addnstr(str, n[, attr])`

`window.addnstr(y, x, str, n[, attr])`

Paint at most *n* characters of the string *str* at (*y*, *x*) with attributes *attr*, overwriting anything previously on the display.

`window.addstr(str[, attr])`

`window.addstr(y, x, str[, attr])`

Paint the string *str* at (*y*, *x*) with attributes *attr*, overwriting anything previously on the display.

`window.attroff(attr)`

Remove attribute *attr* from the “background” set applied to all writes to the current window.

`window.attron(attr)`

Add attribute *attr* from the “background” set applied to all writes to the current window.

`window.attrset(attr)`

Set the “background” set of attributes to *attr*. This set is initially 0 (no attributes).

`window.bkgd(ch[, attr])`

Set the background property of the window to the character *ch*, with attributes *attr*. The change is then applied to every character position in that window:

- The attribute of every character in the window is changed to the new background attribute.
- Wherever the former background character appears, it is changed to the new background character.

`window.bkgdset(ch[, attr])`

Set the window’s background. A window’s background consists of a character and any combination of attributes. The attribute part of the background is combined (OR’ed) with all non-blank characters that are written into the window. Both the character and attribute parts of the background are combined with the blank characters. The background becomes a property of the character and moves with the character through any scrolling and insert/delete line/character operations.

`window.border([ls[, rs[, ts[, bs[, tl[, tr[, bl[, br]]]]]]])`

Draw a border around the edges of the window. Each parameter specifies the character to use for a specific part of the border; see the table below for more details. The characters can be specified as integers or as one-character strings.

**Note:** A 0 value for any parameter will cause the default character to be used for that parameter. Keyword parameters can *not* be used. The defaults are listed in this table:

Parameter	Description	Default value
<i>ls</i>	Left side	ACS_VLINE
<i>rs</i>	Right side	ACS_VLINE
<i>ts</i>	Top	ACS_HLINE
<i>bs</i>	Bottom	ACS_HLINE
<i>tl</i>	Upper-left corner	ACS_ULCORNER
<i>tr</i>	Upper-right corner	ACS_URCORNER
<i>bl</i>	Bottom-left corner	ACS_LLCORNER
<i>br</i>	Bottom-right corner	ACS_LRCORNER

`window.box([vertch, horch])`

Similar to `border()`, but both *ls* and *rs* are *vertch* and both *ts* and *bs* are *horch*. The default corner characters are always used by this function.

`window.chgat(attr)`

`window.chgat (num, attr)`

`window.chgat (y, x, attr)`

`window.chgat (y, x, num, attr)`

Set the attributes of *num* characters at the current cursor position, or at position (*y*, *x*) if supplied. If no value of *num* is given or *num* = -1, the attribute will be set on all the characters to the end of the line. This function does not move the cursor. The changed line will be touched using the `touchline()` method so that the contents will be redisplayed by the next window refresh.

`window.clear()`

Like `erase()`, but also cause the whole window to be repainted upon next call to `refresh()`.

`window.clearok (yes)`

If *yes* is 1, the next call to `refresh()` will clear the window completely.

`window.clrtoeol()`

Erase from cursor to the end of the window: all lines below the cursor are deleted, and then the equivalent of `clrtoeol()` is performed.

`window.clrtoeol()`

Erase from cursor to the end of the line.

`window.cursyncup()`

Update the current cursor position of all the ancestors of the window to reflect the current cursor position of the window.

`window.delch ([y, x])`

Delete any character at (*y*, *x*).

`window.deleteln()`

Delete the line under the cursor. All following lines are moved up by one line.

`window.derwin (begin_y, begin_x)`

`window.derwin (nlines, ncols, begin_y, begin_x)`

An abbreviation for “derive window”, `derwin()` is the same as calling `subwin()`, except that *begin\_y* and *begin\_x* are relative to the origin of the window, rather than relative to the entire screen. Return a window object for the derived window.

`window.echochar (ch[, attr])`

Add character *ch* with attribute *attr*, and immediately call `refresh()` on the window.

`window.enclose (y, x)`

Test whether the given pair of screen-relative character-cell coordinates are enclosed by the given window, returning True or False. It is useful for determining what subset of the screen windows enclose the location of a mouse event.

`window.erase()`

Clear the window.

`window.getbegyx()`

Return a tuple (*y*, *x*) of co-ordinates of upper-left corner.

`window.getbkgd()`

Return the given window’s current background character/attribute pair.

`window.getch ([y, x])`

Get a character. Note that the integer returned does *not* have to be in ASCII range: function keys, keypad keys and so on return numbers higher than 256. In no-delay mode, -1 is returned if there is no input, else `getch()` waits until a key is pressed.

`window.getkey ([y, x])`

Get a character, returning a string instead of an integer, as `getch()` does. Function keys, keypad keys and so

on return a multibyte string containing the key name. In no-delay mode, an exception is raised if there is no input.

`window.getmaxyx()`

Return a tuple  $(y, x)$  of the height and width of the window.

`window.getparyx()`

Return the beginning coordinates of this window relative to its parent window into two integer variables  $y$  and  $x$ . Return  $-1, -1$  if this window has no parent.

`window.getstr([y, x])`

Read a string from the user, with primitive line editing capacity.

`window.getyx()`

Return a tuple  $(y, x)$  of current cursor position relative to the window's upper-left corner.

`window.hline(ch, n)`

`window.hline(y, x, ch, n)`

Display a horizontal line starting at  $(y, x)$  with length  $n$  consisting of the character  $ch$ .

`window.idcok(flag)`

If  $flag$  is `False`, curses no longer considers using the hardware insert/delete character feature of the terminal; if  $flag$  is `True`, use of character insertion and deletion is enabled. When curses is first initialized, use of character insert/delete is enabled by default.

`window.idlok(yes)`

If called with  $yes$  equal to `1`, `curses` will try and use hardware line editing facilities. Otherwise, line insertion/deletion are disabled.

`window.immedok(flag)`

If  $flag$  is `True`, any change in the window image automatically causes the window to be refreshed; you no longer have to call `refresh()` yourself. However, it may degrade performance considerably, due to repeated calls to `wrefresh`. This option is disabled by default.

`window.inch([y, x])`

Return the character at the given position in the window. The bottom 8 bits are the character proper, and upper bits are the attributes.

`window.insch(ch[, attr])`

`window.insch(y, x, ch[, attr])`

Paint character  $ch$  at  $(y, x)$  with attributes  $attr$ , moving the line from position  $x$  right by one character.

`window.insdelln(nlines)`

Insert  $nlines$  lines into the specified window above the current line. The  $nlines$  bottom lines are lost. For negative  $nlines$ , delete  $nlines$  lines starting with the one under the cursor, and move the remaining lines up. The bottom  $nlines$  lines are cleared. The current cursor position remains the same.

`window.insertln()`

Insert a blank line under the cursor. All following lines are moved down by one line.

`window.insnstr(str, n[, attr])`

`window.insnstr(y, x, str, n[, attr])`

Insert a character string (as many characters as will fit on the line) before the character under the cursor, up to  $n$  characters. If  $n$  is zero or negative, the entire string is inserted. All characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to  $y, x$ , if specified).

`window.insstr(str[, attr])`

`window.insstr(y, x, str[, attr])`

Insert a character string (as many characters as will fit on the line) before the character under the cursor. All

characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to *y*, *x*, if specified).

`window.instr([n])`

`window.instr(y, x[, n])`

Return a string of characters, extracted from the window starting at the current cursor position, or at *y*, *x* if specified. Attributes are stripped from the characters. If *n* is specified, `instr()` returns a string at most *n* characters long (exclusive of the trailing NUL).

`window.is_linetouched(line)`

Return True if the specified line was modified since the last call to `refresh()`; otherwise return False. Raise a `curses.error` exception if *line* is not valid for the given window.

`window.is_wintouched()`

Return True if the specified window was modified since the last call to `refresh()`; otherwise return False.

`window.keypad(yes)`

If *yes* is 1, escape sequences generated by some keys (keypad, function keys) will be interpreted by `curses`. If *yes* is 0, escape sequences will be left as is in the input stream.

`window.leaveok(yes)`

If *yes* is 1, cursor is left where it is on update, instead of being at “cursor position.” This reduces cursor movement where possible. If possible the cursor will be made invisible.

If *yes* is 0, cursor will always be at “cursor position” after an update.

`window.move(new_y, new_x)`

Move cursor to (*new\_y*, *new\_x*).

`window.mvderwin(y, x)`

Move the window inside its parent window. The screen-relative parameters of the window are not changed. This routine is used to display different parts of the parent window at the same physical position on the screen.

`window.mvwin(new_y, new_x)`

Move the window so its upper-left corner is at (*new\_y*, *new\_x*).

`window.nodelay(yes)`

If *yes* is 1, `getch()` will be non-blocking.

`window.notimeout(yes)`

If *yes* is 1, escape sequences will not be timed out.

If *yes* is 0, after a few milliseconds, an escape sequence will not be interpreted, and will be left in the input stream as is.

`window.noutrefresh()`

Mark for refresh but wait. This function updates the data structure representing the desired state of the window, but does not force an update of the physical screen. To accomplish that, call `doupdate()`.

`window.overlay(destwin[, sminrow, smincol, dminrow, dmincol, dmaxrow, dmaxcol])`

Overlay the window on top of *destwin*. The windows need not be the same size, only the overlapping region is copied. This copy is non-destructive, which means that the current background character does not overwrite the old contents of *destwin*.

To get fine-grained control over the copied region, the second form of `overlay()` can be used. *sminrow* and *smincol* are the upper-left coordinates of the source window, and the other variables mark a rectangle in the destination window.

`window.overwrite(destwin[, sminrow, smincol, dminrow, dmincol, dmaxrow, dmaxcol])`

Overwrite the window on top of *destwin*. The windows need not be the same size, in which case only the overlapping region is copied. This copy is destructive, which means that the current background character overwrites the old contents of *destwin*.

To get fine-grained control over the copied region, the second form of `overwrite()` can be used. `sminrow` and `smincol` are the upper-left coordinates of the source window, the other variables mark a rectangle in the destination window.

`window.putwin` (*file*)

Write all data associated with the window into the provided file object. This information can be later retrieved using the `getwin()` function.

`window.redrawln` (*beg*, *num*)

Indicate that the *num* screen lines, starting at line *beg*, are corrupted and should be completely redrawn on the next `refresh()` call.

`window.redrawwin` ()

Touch the entire window, causing it to be completely redrawn on the next `refresh()` call.

`window.refresh` ([*pminrow*, *pmincol*, *sminrow*, *smincol*, *smaxrow*, *smaxcol*])

Update the display immediately (sync actual screen with previous drawing/deleting methods).

The 6 optional arguments can only be specified when the window is a pad created with `newpad()`. The additional parameters are needed to indicate what part of the pad and screen are involved. *pminrow* and *pmincol* specify the upper left-hand corner of the rectangle to be displayed in the pad. *sminrow*, *smincol*, *smaxrow*, and *smaxcol* specify the edges of the rectangle to be displayed on the screen. The lower right-hand corner of the rectangle to be displayed in the pad is calculated from the screen coordinates, since the rectangles must be the same size. Both rectangles must be entirely contained within their respective structures. Negative values of *pminrow*, *pmincol*, *sminrow*, or *smincol* are treated as if they were zero.

`window.resize` (*nlines*, *ncols*)

Reallocate storage for a curses window to adjust its dimensions to the specified values. If either dimension is larger than the current values, the window's data is filled with blanks that have the current background rendition (as set by `bkgdset()`) merged into them.

`window.scroll` ([*lines=1*])

Scroll the screen or scrolling region upward by *lines* lines.

`window.scrollok` (*flag*)

Control what happens when the cursor of a window is moved off the edge of the window or scrolling region, either as a result of a newline action on the bottom line, or typing the last character of the last line. If *flag* is false, the cursor is left on the bottom line. If *flag* is true, the window is scrolled up one line. Note that in order to get the physical scrolling effect on the terminal, it is also necessary to call `idlok()`.

`window.setscrreg` (*top*, *bottom*)

Set the scrolling region from line *top* to line *bottom*. All scrolling actions will take place in this region.

`window.standend` ()

Turn off the standout attribute. On some terminals this has the side effect of turning off all attributes.

`window.standout` ()

Turn on attribute `A_STANDOUT`.

`window.subpad` (*begin\_y*, *begin\_x*)

`window.subpad` (*nlines*, *ncols*, *begin\_y*, *begin\_x*)

Return a sub-window, whose upper-left corner is at (*begin\_y*, *begin\_x*), and whose width/height is *ncols/nlines*.

`window.subwin` (*begin\_y*, *begin\_x*)

`window.subwin` (*nlines*, *ncols*, *begin\_y*, *begin\_x*)

Return a sub-window, whose upper-left corner is at (*begin\_y*, *begin\_x*), and whose width/height is *ncols/nlines*.

By default, the sub-window will extend from the specified position to the lower right corner of the window.

`window.syncdown()`

Touch each location in the window that has been touched in any of its ancestor windows. This routine is called by `refresh()`, so it should almost never be necessary to call it manually.

`window.syncok(flag)`

If called with `flag` set to `True`, then `syncup()` is called automatically whenever there is a change in the window.

`window.syncup()`

Touch all locations in ancestors of the window that have been changed in the window.

`window.timeout(delay)`

Set blocking or non-blocking read behavior for the window. If `delay` is negative, blocking read is used (which will wait indefinitely for input). If `delay` is zero, then non-blocking read is used, and `-1` will be returned by `getch()` if no input is waiting. If `delay` is positive, then `getch()` will block for `delay` milliseconds, and return `-1` if there is still no input at the end of that time.

`window.touchline(start, count[, changed])`

Pretend `count` lines have been changed, starting with line `start`. If `changed` is supplied, it specifies whether the affected lines are marked as having been changed (`changed=1`) or unchanged (`changed=0`).

`window.touchwin()`

Pretend the whole window has been changed, for purposes of drawing optimizations.

`window.untouchwin()`

Mark all lines in the window as unchanged since the last call to `refresh()`.

`window.vline(ch, n)`

`window.vline(y, x, ch, n)`

Display a vertical line starting at  $(y, x)$  with length `n` consisting of the character `ch`.

### 15.11.3 Constants

The `curses` module defines the following data members:

`curses.ERR`

Some curses routines that return an integer, such as `getch()`, return `ERR` upon failure.

`curses.OK`

Some curses routines that return an integer, such as `napms()`, return `OK` upon success.

`curses.version`

A string representing the current version of the module. Also available as `__version__`.

Several constants are available to specify character cell attributes:

Attribute	Meaning
<code>A_ALTCHARSET</code>	Alternate character set mode.
<code>A_BLINK</code>	Blink mode.
<code>A_BOLD</code>	Bold mode.
<code>A_DIM</code>	Dim mode.
<code>A_NORMAL</code>	Normal attribute.
<code>A_REVERSE</code>	Reverse background and foreground colors.
<code>A_STANDOUT</code>	Standout mode.
<code>A_UNDERLINE</code>	Underline mode.

Keys are referred to by integer constants with names starting with `KEY_`. The exact keycaps available are system dependent.

Key constant	Key
KEY_MIN	Minimum key value
KEY_BREAK	Break key (unreliable)
KEY_DOWN	Down-arrow
KEY_UP	Up-arrow
KEY_LEFT	Left-arrow
KEY_RIGHT	Right-arrow
KEY_HOME	Home key (upward+left arrow)
KEY_BACKSPACE	Backspace (unreliable)
KEY_F0	Function keys. Up to 64 function keys are supported.
KEY_Fn	Value of function key <i>n</i>
KEY_DL	Delete line
KEY_IL	Insert line
KEY_DC	Delete character
KEY_IC	Insert char or enter insert mode
KEY_EIC	Exit insert char mode
KEY_CLEAR	Clear screen
KEY_EOS	Clear to end of screen
KEY_EOL	Clear to end of line
KEY_SF	Scroll 1 line forward
KEY_SR	Scroll 1 line backward (reverse)
KEY_NPAGE	Next page
KEY_PPAGE	Previous page
KEY_STAB	Set tab
KEY_CTAB	Clear tab
KEY_CATAB	Clear all tabs
KEY_ENTER	Enter or send (unreliable)
KEY_SRESET	Soft (partial) reset (unreliable)
KEY_RESET	Reset or hard reset (unreliable)
KEY_PRINT	Print
KEY_LL	Home down or bottom (lower left)
KEY_A1	Upper left of keypad
KEY_A3	Upper right of keypad
KEY_B2	Center of keypad
KEY_C1	Lower left of keypad
KEY_C3	Lower right of keypad
KEY_BTAB	Back tab
KEY_BEG	Beg (beginning)
KEY_CANCEL	Cancel
KEY_CLOSE	Close
KEY_COMMAND	Cmd (command)
KEY_COPY	Copy
KEY_CREATE	Create
KEY_END	End
KEY_EXIT	Exit
KEY_FIND	Find
KEY_HELP	Help
KEY_MARK	Mark
KEY_MESSAGE	Message
KEY_MOVE	Move
KEY_NEXT	Next
KEY_OPEN	Open

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KEY_OPTIONS	Options
KEY_PREVIOUS	Prev (previous)
KEY_REDO	Redo
KEY_REFERENCE	Ref (reference)
KEY_REFRESH	Refresh
KEY_REPLACE	Replace
KEY_RESTART	Restart
KEY_RESUME	Resume
KEY_SAVE	Save
KEY_SBEG	Shifted Beg (beginning)
KEY_SCANCEL	Shifted Cancel
KEY_SCOMMAND	Shifted Command
KEY_SCOPY	Shifted Copy
KEY_SCREATE	Shifted Create
KEY_SDC	Shifted Delete char
KEY_SDL	Shifted Delete line
KEY_SELECT	Select
KEY_SEND	Shifted End
KEY_SEOL	Shifted Clear line
KEY_SEXIT	Shifted Dxit
KEY_SFIND	Shifted Find
KEY_SHELP	Shifted Help
KEY_SHOME	Shifted Home
KEY_SIC	Shifted Input
KEY_SLEFT	Shifted Left arrow
KEY_SMESSAGE	Shifted Message
KEY_SMOVE	Shifted Move
KEY_SNEXT	Shifted Next
KEY_SOPTIONS	Shifted Options
KEY_SPREVIOUS	Shifted Prev
KEY_SPRINT	Shifted Print
KEY_SREDO	Shifted Redo
KEY_SREPLACE	Shifted Replace
KEY_SRIGHT	Shifted Right arrow
KEY_SRSUME	Shifted Resume
KEY_SSAVE	Shifted Save
KEY_SSUSPEND	Shifted Suspend
KEY_SUNDO	Shifted Undo
KEY_SUSPEND	Suspend
KEY_UNDO	Undo
KEY_MOUSE	Mouse event has occurred
KEY_RESIZE	Terminal resize event
KEY_MAX	Maximum key value

On VT100s and their software emulations, such as X terminal emulators, there are normally at least four function keys (KEY\_F1, KEY\_F2, KEY\_F3, KEY\_F4) available, and the arrow keys mapped to KEY\_UP, KEY\_DOWN, KEY\_LEFT and KEY\_RIGHT in the obvious way. If your machine has a PC keyboard, it is safe to expect arrow keys and twelve function keys (older PC keyboards may have only ten function keys); also, the following keypad mappings are standard:

Keycap	Constant
Insert	KEY_IC
Delete	KEY_DC
Home	KEY_HOME
End	KEY_END
Page Up	KEY_NPAGE
Page Down	KEY_PPAGE

The following table lists characters from the alternate character set. These are inherited from the VT100 terminal, and will generally be available on software emulations such as X terminals. When there is no graphic available, curses falls back on a crude printable ASCII approximation.

**Note:** These are available only after `initscr()` has been called.

ACS code	Meaning
ACS_BBSS	alternate name for upper right corner
ACS_BLOCK	solid square block
ACS_BOARD	board of squares
ACS_BSBS	alternate name for horizontal line
ACS_BSSB	alternate name for upper left corner
ACS_BSSS	alternate name for top tee
ACS_BTEE	bottom tee
ACS_BULLET	bullet
ACS_CKBOARD	checker board (stipple)
ACS_DARROW	arrow pointing down
ACS_DEGREE	degree symbol
ACS_DIAMOND	diamond
ACS_GEQUAL	greater-than-or-equal-to
ACS_HLINE	horizontal line
ACS_LANTERN	lantern symbol
ACS_LARROW	left arrow
ACS_LEQUAL	less-than-or-equal-to
ACS_LLCORNER	lower left-hand corner
ACS_LRCORNER	lower right-hand corner
ACS_LTEE	left tee
ACS_NEQUAL	not-equal sign
ACS_PI	letter pi
ACS_PLMINUS	plus-or-minus sign
ACS_PLUS	big plus sign
ACS_RARROW	right arrow
ACS_RTEE	right tee
ACS_S1	scan line 1
ACS_S3	scan line 3
ACS_S7	scan line 7
ACS_S9	scan line 9
ACS_SBBS	alternate name for lower right corner
ACS_SBSB	alternate name for vertical line
ACS_SBSS	alternate name for right tee
ACS_SSBB	alternate name for lower left corner
ACS_SSBS	alternate name for bottom tee
ACS_SSSB	alternate name for left tee
ACS_SSSS	alternate name for crossover or big plus
ACS_STERLING	pound sterling

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Table 15.2 – continued from previous page

ACS_TTEE	top tee
ACS_UARROW	up arrow
ACS_ULCORNER	upper left corner
ACS_URCORNER	upper right corner
ACS_VLINE	vertical line

The following table lists the predefined colors:

Constant	Color
COLOR_BLACK	Black
COLOR_BLUE	Blue
COLOR_CYAN	Cyan (light greenish blue)
COLOR_GREEN	Green
COLOR_MAGENTA	Magenta (purplish red)
COLOR_RED	Red
COLOR_WHITE	White
COLOR_YELLOW	Yellow

## 15.12 `curses.textpad` — Text input widget for curses programs

New in version 1.6. The `curses.textpad` module provides a `Textbox` class that handles elementary text editing in a curses window, supporting a set of keybindings resembling those of Emacs (thus, also of Netscape Navigator, BEdit 6.x, FrameMaker, and many other programs). The module also provides a rectangle-drawing function useful for framing text boxes or for other purposes.

The module `curses.textpad` defines the following function:

`curses.textpad.rectangle` (*win, uly, ulx, lry, lrx*)

Draw a rectangle. The first argument must be a window object; the remaining arguments are coordinates relative to that window. The second and third arguments are the y and x coordinates of the upper left hand corner of the rectangle to be drawn; the fourth and fifth arguments are the y and x coordinates of the lower right hand corner. The rectangle will be drawn using VT100/IBM PC forms characters on terminals that make this possible (including xterm and most other software terminal emulators). Otherwise it will be drawn with ASCII dashes, vertical bars, and plus signs.

### 15.12.1 Textbox objects

You can instantiate a `Textbox` object as follows:

**class** `curses.textpad.Textbox` (*win*)

Return a textbox widget object. The *win* argument should be a `curses.WindowObject` in which the textbox is to be contained. The edit cursor of the textbox is initially located at the upper left hand corner of the containing window, with coordinates (0, 0). The instance's `stripspaces` flag is initially on.

`Textbox` objects have the following methods:

**edit** (*[validator]*)

This is the entry point you will normally use. It accepts editing keystrokes until one of the termination keystrokes is entered. If *validator* is supplied, it must be a function. It will be called for each keystroke entered with the keystroke as a parameter; command dispatch is done on the result. This method returns the window contents as a string; whether blanks in the window are included is affected by the `stripspaces` attribute.

**do\_command** (*ch*)

Process a single command keystroke. Here are the supported special keystrokes:

Keystroke	Action
Control-A	Go to left edge of window.
Control-B	Cursor left, wrapping to previous line if appropriate.
Control-D	Delete character under cursor.
Control-E	Go to right edge (stripspaces off) or end of line (stripspaces on).
Control-F	Cursor right, wrapping to next line when appropriate.
Control-G	Terminate, returning the window contents.
Control-H	Delete character backward.
Control-J	Terminate if the window is 1 line, otherwise insert newline.
Control-K	If line is blank, delete it, otherwise clear to end of line.
Control-L	Refresh screen.
Control-N	Cursor down; move down one line.
Control-O	Insert a blank line at cursor location.
Control-P	Cursor up; move up one line.

Move operations do nothing if the cursor is at an edge where the movement is not possible. The following synonyms are supported where possible:

Constant	Keystroke
KEY_LEFT	Control-B
KEY_RIGHT	Control-F
KEY_UP	Control-P
KEY_DOWN	Control-N
KEY_BACKSPACE	Control-h

All other keystrokes are treated as a command to insert the given character and move right (with line wrapping).

**gather** ()

Return the window contents as a string; whether blanks in the window are included is affected by the `stripspaces` member.

**stripspaces**

This attribute is a flag which controls the interpretation of blanks in the window. When it is on, trailing blanks on each line are ignored; any cursor motion that would land the cursor on a trailing blank goes to the end of that line instead, and trailing blanks are stripped when the window contents are gathered.

## 15.13 `curses.ascii` — Utilities for ASCII characters

New in version 1.6. The `curses.ascii` module supplies name constants for ASCII characters and functions to test membership in various ASCII character classes. The constants supplied are names for control characters as follows:

Name	Meaning
NUL	
SOH	Start of heading, console interrupt
STX	Start of text
ETX	End of text
EOT	End of transmission
ENQ	Enquiry, goes with ACK flow control
ACK	Acknowledgement
BEL	Bell
Continued on next page	

Table 15.3 – continued from previous page

BS	Backspace
TAB	Tab
HT	Alias for TAB: “Horizontal tab”
LF	Line feed
NL	Alias for LF: “New line”
VT	Vertical tab
FF	Form feed
CR	Carriage return
SO	Shift-out, begin alternate character set
SI	Shift-in, resume default character set
DLE	Data-link escape
DC1	XON, for flow control
DC2	Device control 2, block-mode flow control
DC3	XOFF, for flow control
DC4	Device control 4
NAK	Negative acknowledgement
SYN	Synchronous idle
ETB	End transmission block
CAN	Cancel
EM	End of medium
SUB	Substitute
ESC	Escape
FS	File separator
GS	Group separator
RS	Record separator, block-mode terminator
US	Unit separator
SP	Space
DEL	Delete

Note that many of these have little practical significance in modern usage. The mnemonics derive from teleprinter conventions that predate digital computers.

The module supplies the following functions, patterned on those in the standard C library:

`curses.ascii.isalnum(c)`

Checks for an ASCII alphanumeric character; it is equivalent to `isalpha(c)` or `isdigit(c)`.

`curses.ascii.isalpha(c)`

Checks for an ASCII alphabetic character; it is equivalent to `isupper(c)` or `islower(c)`.

`curses.ascii.isascii(c)`

Checks for a character value that fits in the 7-bit ASCII set.

`curses.ascii.isblank(c)`

Checks for an ASCII whitespace character.

`curses.ascii.iscntrl(c)`

Checks for an ASCII control character (in the range 0x00 to 0x1f).

`curses.ascii.isdigit(c)`

Checks for an ASCII decimal digit, '0' through '9'. This is equivalent to `c` in `string.digits`.

`curses.ascii.isgraph(c)`

Checks for ASCII any printable character except space.

`curses.ascii.islower(c)`

Checks for an ASCII lower-case character.

`curses.ascii.isprint(c)`

Checks for any ASCII printable character including space.

`curses.ascii.ispunct(c)`

Checks for any printable ASCII character which is not a space or an alphanumeric character.

`curses.ascii.isspace(c)`

Checks for ASCII white-space characters; space, line feed, carriage return, form feed, horizontal tab, vertical tab.

`curses.ascii.isupper(c)`

Checks for an ASCII uppercase letter.

`curses.ascii.isxdigit(c)`

Checks for an ASCII hexadecimal digit. This is equivalent to `c in string.hexdigits`.

`curses.ascii.isctrl(c)`

Checks for an ASCII control character (ordinal values 0 to 31).

`curses.ascii.ismeta(c)`

Checks for a non-ASCII character (ordinal values 0x80 and above).

These functions accept either integers or strings; when the argument is a string, it is first converted using the built-in function `ord()`.

Note that all these functions check ordinal bit values derived from the first character of the string you pass in; they do not actually know anything about the host machine's character encoding. For functions that know about the character encoding (and handle internationalization properly) see the `string` module.

The following two functions take either a single-character string or integer byte value; they return a value of the same type.

`curses.ascii.ascii(c)`

Return the ASCII value corresponding to the low 7 bits of *c*.

`curses.ascii.ctrl(c)`

Return the control character corresponding to the given character (the character bit value is bitwise-anded with 0x1f).

`curses.ascii.alt(c)`

Return the 8-bit character corresponding to the given ASCII character (the character bit value is bitwise-ored with 0x80).

The following function takes either a single-character string or integer value; it returns a string.

`curses.ascii.unctrl(c)`

Return a string representation of the ASCII character *c*. If *c* is printable, this string is the character itself. If the character is a control character (0x00-0x1f) the string consists of a caret ('^') followed by the corresponding uppercase letter. If the character is an ASCII delete (0x7f) the string is '^?'. If the character has its meta bit (0x80) set, the meta bit is stripped, the preceding rules applied, and '! ' prepended to the result.

`curses.ascii.controlnames`

A 33-element string array that contains the ASCII mnemonics for the thirty-two ASCII control characters from 0 (NUL) to 0x1f (US), in order, plus the mnemonic `SP` for the space character.

## 15.14 `curses.panel` — A panel stack extension for curses

Panels are windows with the added feature of depth, so they can be stacked on top of each other, and only the visible portions of each window will be displayed. Panels can be added, moved up or down in the stack, and removed.

### 15.14.1 Functions

The module `curses.panel` defines the following functions:

`curses.panel.bottom_panel()`

Returns the bottom panel in the panel stack.

`curses.panel.new_panel(win)`

Returns a panel object, associating it with the given window *win*. Be aware that you need to keep the returned panel object referenced explicitly. If you don't, the panel object is garbage collected and removed from the panel stack.

`curses.panel.top_panel()`

Returns the top panel in the panel stack.

`curses.panel.update_panels()`

Updates the virtual screen after changes in the panel stack. This does not call `curses.doupdate()`, so you'll have to do this yourself.

### 15.14.2 Panel Objects

Panel objects, as returned by `new_panel()` above, are windows with a stacking order. There's always a window associated with a panel which determines the content, while the panel methods are responsible for the window's depth in the panel stack.

Panel objects have the following methods:

`Panel.above()`

Returns the panel above the current panel.

`Panel.below()`

Returns the panel below the current panel.

`Panel.bottom()`

Push the panel to the bottom of the stack.

`Panel.hidden()`

Returns true if the panel is hidden (not visible), false otherwise.

`Panel.hide()`

Hide the panel. This does not delete the object, it just makes the window on screen invisible.

`Panel.move(y, x)`

Move the panel to the screen coordinates (*y*, *x*).

`Panel.replace(win)`

Change the window associated with the panel to the window *win*.

`Panel.set_userptr(obj)`

Set the panel's user pointer to *obj*. This is used to associate an arbitrary piece of data with the panel, and can be any Python object.

`Panel.show()`

Display the panel (which might have been hidden).

`Panel.top()`

Push panel to the top of the stack.

`Panel.userptr()`

Returns the user pointer for the panel. This might be any Python object.

`Panel.window()`

Returns the window object associated with the panel.

## 15.15 `platform` — Access to underlying platform’s identifying data

New in version 2.3. **Source code:** [Lib/platform.py](#)

---

**Note:** Specific platforms listed alphabetically, with Linux included in the Unix section.

---

### 15.15.1 Cross Platform

`platform.architecture(executable=sys.executable, bits='', linkage='')`

Queries the given executable (defaults to the Python interpreter binary) for various architecture information.

Returns a tuple (`bits`, `linkage`) which contain information about the bit architecture and the linkage format used for the executable. Both values are returned as strings.

Values that cannot be determined are returned as given by the parameter presets. If `bits` is given as "", the `sizeof(pointer)()` (or `sizeof(long)()` on Python version < 1.5.2) is used as indicator for the supported pointer size.

The function relies on the system’s `file` command to do the actual work. This is available on most if not all Unix platforms and some non-Unix platforms and then only if the executable points to the Python interpreter. Reasonable defaults are used when the above needs are not met.

---

**Note:** On Mac OS X (and perhaps other platforms), executable files may be universal files containing multiple architectures.

To get at the “64-bitness” of the current interpreter, it is more reliable to query the `sys.maxsize` attribute:

```
is_64bits = sys.maxsize > 2**32
```

---

`platform.machine()`

Returns the machine type, e.g. 'i386'. An empty string is returned if the value cannot be determined.

`platform.node()`

Returns the computer’s network name (may not be fully qualified!). An empty string is returned if the value cannot be determined.

`platform.platform(aliased=0, terse=0)`

Returns a single string identifying the underlying platform with as much useful information as possible.

The output is intended to be *human readable* rather than machine parseable. It may look different on different platforms and this is intended.

If *aliased* is true, the function will use aliases for various platforms that report system names which differ from their common names, for example SunOS will be reported as Solaris. The `system_alias()` function is used to implement this.

Setting *terse* to true causes the function to return only the absolute minimum information needed to identify the platform.

`platform.processor()`

Returns the (real) processor name, e.g. 'amd64'.

An empty string is returned if the value cannot be determined. Note that many platforms do not provide this information or simply return the same value as for `machine()`. NetBSD does this.

`platform.python_build()`

Returns a tuple (`buildno`, `builddate`) stating the Python build number and date as strings.

`platform.python_compiler()`

Returns a string identifying the compiler used for compiling Python.

`platform.python_branch()`

Returns a string identifying the Python implementation SCM branch. New in version 2.6.

`platform.python_implementation()`

Returns a string identifying the Python implementation. Possible return values are: 'CPython', 'IronPython', 'Jython', 'PyPy'. New in version 2.6.

`platform.python_revision()`

Returns a string identifying the Python implementation SCM revision. New in version 2.6.

`platform.python_version()`

Returns the Python version as string 'major.minor.patchlevel'

Note that unlike the Python `sys.version`, the returned value will always include the patchlevel (it defaults to 0).

`platform.python_version_tuple()`

Returns the Python version as tuple (`major`, `minor`, `patchlevel`) of strings.

Note that unlike the Python `sys.version`, the returned value will always include the patchlevel (it defaults to '0').

`platform.release()`

Returns the system's release, e.g. '2.2.0' or 'NT'. An empty string is returned if the value cannot be determined.

`platform.system()`

Returns the system/OS name, e.g. 'Linux', 'Windows', or 'Java'. An empty string is returned if the value cannot be determined.

`platform.system_alias(system, release, version)`

Returns (`system`, `release`, `version`) aliased to common marketing names used for some systems. It also does some reordering of the information in some cases where it would otherwise cause confusion.

`platform.version()`

Returns the system's release version, e.g. '#3 on degas'. An empty string is returned if the value cannot be determined.

`platform.uname()`

Fairly portable uname interface. Returns a tuple of strings (`system`, `node`, `release`, `version`, `machine`, `processor`) identifying the underlying platform.

Note that unlike the `os.uname()` function this also returns possible processor information as additional tuple entry.

Entries which cannot be determined are set to ''.

### 15.15.2 Java Platform

`platform.java_ver` (*release*='', *vendor*='', *vminfo*=('', '', ''), *osinfo*=('', '', ''))  
Version interface for Jython.

Returns a tuple (*release*, *vendor*, *vminfo*, *osinfo*) with *vminfo* being a tuple (*vm\_name*, *vm\_release*, *vm\_vendor*) and *osinfo* being a tuple (*os\_name*, *os\_version*, *os\_arch*). Values which cannot be determined are set to the defaults given as parameters (which all default to "").

### 15.15.3 Windows Platform

`platform.win32_ver` (*release*='', *version*='', *csd*='', *ptype*='')

Get additional version information from the Windows Registry and return a tuple (*version*, *csd*, *ptype*) referring to version number, CSD level (service pack) and OS type (multi/single processor).

As a hint: *ptype* is 'Uniprocessor Free' on single processor NT machines and 'Multiprocessor Free' on multi processor machines. The 'Free' refers to the OS version being free of debugging code. It could also state 'Checked' which means the OS version uses debugging code, i.e. code that checks arguments, ranges, etc.

---

**Note:** This function works best with Mark Hammond's `win32all` package installed, but also on Python 2.3 and later (support for this was added in Python 2.6). It obviously only runs on Win32 compatible platforms.

---

#### Win95/98 specific

`platform.popen` (*cmd*, *mode*='r', *bufsize*=None)

Portable `popen()` interface. Find a working `popen` implementation preferring `win32pipe.popen()`. On Windows NT, `win32pipe.popen()` should work; on Windows 9x it hangs due to bugs in the MS C library.

### 15.15.4 Mac OS Platform

`platform.mac_ver` (*release*='', *versioninfo*=('', '', ''), *machine*='')

Get Mac OS version information and return it as tuple (*release*, *versioninfo*, *machine*) with *versioninfo* being a tuple (*version*, *dev\_stage*, *non\_release\_version*).

Entries which cannot be determined are set to "". All tuple entries are strings.

### 15.15.5 Unix Platforms

`platform.dist` (*distname*='', *version*='', *id*='', *supported\_dists*=('SuSE', 'debian', 'redhat', 'mandrake', ...))

This is an old version of the functionality now provided by `linux_distribution()`. For new code, please use the `linux_distribution()`.

The only difference between the two is that `dist()` always returns the short name of the distribution taken from the `supported_dists` parameter. Deprecated since version 2.6.

`platform.linux_distribution` (*distname*='', *version*='', *id*='', *supported\_dists*=('SuSE', 'debian', 'redhat', 'mandrake', ...), *full\_distribution\_name*=1)

Tries to determine the name of the Linux OS distribution name.

`supported_dists` may be given to define the set of Linux distributions to look for. It defaults to a list of currently supported Linux distributions identified by their release file name.

If `full_distribution_name` is `true` (default), the full distribution read from the OS is returned. Otherwise the short name taken from `supported_dists` is used.

Returns a tuple (`distname`, `version`, `id`) which defaults to the args given as parameters. `id` is the item in parentheses after the version number. It is usually the version codename. New in version 2.6.

`platform.libc_ver` (*executable=sys.executable, lib='', version='', chunksize=2048*)

Tries to determine the libc version against which the file `executable` (defaults to the Python interpreter) is linked. Returns a tuple of strings (`lib`, `version`) which default to the given parameters in case the lookup fails.

Note that this function has intimate knowledge of how different libc versions add symbols to the executable is probably only usable for executables compiled using `gcc`.

The file is read and scanned in chunks of `chunksize` bytes.

## 15.16 `errno` — Standard `errno` system symbols

This module makes available standard `errno` system symbols. The value of each symbol is the corresponding integer value. The names and descriptions are borrowed from `linux/include/errno.h`, which should be pretty all-inclusive.

`errno.errorcode`

Dictionary providing a mapping from the `errno` value to the string name in the underlying system. For instance, `errno.errorcode[errno.EPERM]` maps to `'EPERM'`.

To translate a numeric error code to an error message, use `os.strerror()`.

Of the following list, symbols that are not used on the current platform are not defined by the module. The specific list of defined symbols is available as `errno.errorcode.keys()`. Symbols available can include:

`errno.EPERM`

Operation not permitted

`errno.ENOENT`

No such file or directory

`errno.ESRCH`

No such process

`errno.EINTR`

Interrupted system call

`errno.EIO`

I/O error

`errno.ENXIO`

No such device or address

`errno.E2BIG`

Arg list too long

`errno.ENOEXEC`

Exec format error

`errno.EBADF`

Bad file number

`errno.ECHILD`

No child processes

`errno.EAGAIN`  
Try again

`errno.ENOMEM`  
Out of memory

`errno.EACCES`  
Permission denied

`errno.EFAULT`  
Bad address

`errno.ENOTBLK`  
Block device required

`errno.EBUSY`  
Device or resource busy

`errno.EEXIST`  
File exists

`errno.EXDEV`  
Cross-device link

`errno.ENODEV`  
No such device

`errno.ENOTDIR`  
Not a directory

`errno.EISDIR`  
Is a directory

`errno.EINVAL`  
Invalid argument

`errno.ENFILE`  
File table overflow

`errno.EMFILE`  
Too many open files

`errno.ENOTTY`  
Not a typewriter

`errno.ETXTBSY`  
Text file busy

`errno.EFBIG`  
File too large

`errno.ENOSPC`  
No space left on device

`errno.ESPIPE`  
Illegal seek

`errno.EROFS`  
Read-only file system

`errno.EMLINK`  
Too many links

`errno.EPIPE`  
Broken pipe

`errno.EDOM`  
Math argument out of domain of func

`errno.ERANGE`  
Math result not representable

`errno.EDEADLK`  
Resource deadlock would occur

`errno.ENAMETOOLONG`  
File name too long

`errno.ENOLCK`  
No record locks available

`errno.ENOSYS`  
Function not implemented

`errno.ENOTEMPTY`  
Directory not empty

`errno.ELOOP`  
Too many symbolic links encountered

`errno.EWOULDBLOCK`  
Operation would block

`errno.ENOMSG`  
No message of desired type

`errno.EIDRM`  
Identifier removed

`errno.ECHRNG`  
Channel number out of range

`errno.EL2NSYNC`  
Level 2 not synchronized

`errno.EL3HLT`  
Level 3 halted

`errno.EL3RST`  
Level 3 reset

`errno.ELNRNG`  
Link number out of range

`errno.EUNATCH`  
Protocol driver not attached

`errno.ENOCSI`  
No CSI structure available

`errno.EL2HLT`  
Level 2 halted

`errno.EBADE`  
Invalid exchange

`errno.EBADR`  
Invalid request descriptor

`errno.EXFULL`  
Exchange full

`errno.ENOANO`  
No anode

`errno.EBADRQC`  
Invalid request code

`errno.EBADSLT`  
Invalid slot

`errno.EDEADLOCK`  
File locking deadlock error

`errno.EBFONT`  
Bad font file format

`errno.ENOSTR`  
Device not a stream

`errno.ENODATA`  
No data available

`errno.ETIME`  
Timer expired

`errno.ENOSR`  
Out of streams resources

`errno.ENONET`  
Machine is not on the network

`errno.ENOPKG`  
Package not installed

`errno.EREMOTE`  
Object is remote

`errno.ENOLINK`  
Link has been severed

`errno.EADV`  
Advertise error

`errno.ESRMNT`  
Srmount error

`errno.ECOMM`  
Communication error on send

`errno.EPROTO`  
Protocol error

`errno.EMULTIHOP`  
Multihop attempted

`errno.EDOTDOT`  
RFS specific error

**errno.EBADMSG**  
Not a data message

**errno.EOVERFLOW**  
Value too large for defined data type

**errno.ENOTUNIQ**  
Name not unique on network

**errno.EBADFD**  
File descriptor in bad state

**errno.EREMCHG**  
Remote address changed

**errno.ELIBACC**  
Can not access a needed shared library

**errno.ELIBBAD**  
Accessing a corrupted shared library

**errno.ELIBSCN**  
.lib section in a.out corrupted

**errno.ELIBMAX**  
Attempting to link in too many shared libraries

**errno.ELIBEXEC**  
Cannot exec a shared library directly

**errno.EILSEQ**  
Illegal byte sequence

**errno.ERESTART**  
Interrupted system call should be restarted

**errno.ESTRPIPE**  
Streams pipe error

**errno.EUSERS**  
Too many users

**errno.ENOTSOCK**  
Socket operation on non-socket

**errno.EDESTADDRREQ**  
Destination address required

**errno.EMSGSIZE**  
Message too long

**errno.EPROTOTYPE**  
Protocol wrong type for socket

**errno.ENOPROTOPT**  
Protocol not available

**errno.EPRONOSUPPORT**  
Protocol not supported

**errno.ESOCKTNOSUPPORT**  
Socket type not supported

**errno.EOPNOTSUPP**  
Operation not supported on transport endpoint

**errno.EPFNOSUPPORT**  
Protocol family not supported

**errno.EAFNOSUPPORT**  
Address family not supported by protocol

**errno.EADDRINUSE**  
Address already in use

**errno.EADDRNOTAVAIL**  
Cannot assign requested address

**errno.ENETDOWN**  
Network is down

**errno.ENETUNREACH**  
Network is unreachable

**errno.ENETRESET**  
Network dropped connection because of reset

**errno.ECONNABORTED**  
Software caused connection abort

**errno.ECONNRESET**  
Connection reset by peer

**errno.ENOBUFS**  
No buffer space available

**errno.EISCONN**  
Transport endpoint is already connected

**errno.ENOTCONN**  
Transport endpoint is not connected

**errno.ESHUTDOWN**  
Cannot send after transport endpoint shutdown

**errno.ETOOMANYREFS**  
Too many references: cannot splice

**errno.ETIMEDOUT**  
Connection timed out

**errno.ECONNREFUSED**  
Connection refused

**errno.EHOSTDOWN**  
Host is down

**errno.EHOSTUNREACH**  
No route to host

**errno.EALREADY**  
Operation already in progress

**errno.EINPROGRESS**  
Operation now in progress

`errno.ESTALE`  
Stale NFS file handle

`errno.EUCLEAN`  
Structure needs cleaning

`errno.ENOTNAM`  
Not a XENIX named type file

`errno.ENAVAIL`  
No XENIX semaphores available

`errno.EISNAM`  
Is a named type file

`errno.EREMOTEIO`  
Remote I/O error

`errno.EDQUOT`  
Quota exceeded

## 15.17 ctypes — A foreign function library for Python

New in version 2.5. `ctypes` is a foreign function library for Python. It provides C compatible data types, and allows calling functions in DLLs or shared libraries. It can be used to wrap these libraries in pure Python.

### 15.17.1 ctypes tutorial

Note: The code samples in this tutorial use `doctest` to make sure that they actually work. Since some code samples behave differently under Linux, Windows, or Mac OS X, they contain `doctest` directives in comments.

Note: Some code samples reference the `ctypes.c_int` type. This type is an alias for the `c_long` type on 32-bit systems. So, you should not be confused if `c_long` is printed if you would expect `c_int` — they are actually the same type.

#### Loading dynamic link libraries

`ctypes` exports the `cdll`, and on Windows `windll` and `oledll` objects, for loading dynamic link libraries.

You load libraries by accessing them as attributes of these objects. `cdll` loads libraries which export functions using the standard `cdecl` calling convention, while `windll` libraries call functions using the `stdcall` calling convention. `oledll` also uses the `stdcall` calling convention, and assumes the functions return a Windows `HRESULT` error code. The error code is used to automatically raise a `WindowsError` exception when the function call fails.

Here are some examples for Windows. Note that `msvcrt` is the MS standard C library containing most standard C functions, and uses the `cdecl` calling convention:

```
>>> from ctypes import *
>>> print windll.kernel32
<WinDLL 'kernel32', handle ... at ...>
>>> print cdll.msvcrt
<CDLL 'msvcrt', handle ... at ...>
>>> libc = cdll.msvcrt
>>>
```

Windows appends the usual `.dll` file suffix automatically.

On Linux, it is required to specify the filename *including* the extension to load a library, so attribute access can not be used to load libraries. Either the `LoadLibrary()` method of the dll loaders should be used, or you should load the library by creating an instance of `CDLL` by calling the constructor:

```
>>> cdll.LoadLibrary("libc.so.6")
<CDLL 'libc.so.6', handle ... at ...>
>>> libc = CDLL("libc.so.6")
>>> libc
<CDLL 'libc.so.6', handle ... at ...>
>>>
```

### Accessing functions from loaded dlls

Functions are accessed as attributes of dll objects:

```
>>> from ctypes import *
>>> libc.printf
<_FuncPtr object at 0x...>
>>> print windll.kernel32.GetModuleHandleA
<_FuncPtr object at 0x...>
>>> print windll.kernel32.MyOwnFunction
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "ctypes.py", line 239, in __getattr__
    func = _StdcallFuncPtr(name, self)
AttributeError: function 'MyOwnFunction' not found
>>>
```

Note that win32 system dlls like `kernel32` and `user32` often export ANSI as well as UNICODE versions of a function. The UNICODE version is exported with an `W` appended to the name, while the ANSI version is exported with an `A` appended to the name. The win32 `GetModuleHandle` function, which returns a *module handle* for a given module name, has the following C prototype, and a macro is used to expose one of them as `GetModuleHandle` depending on whether UNICODE is defined or not:

```
/* ANSI version */
HMODULE GetModuleHandleA(LPCSTR lpModuleName);
/* UNICODE version */
HMODULE GetModuleHandleW(LPCWSTR lpModuleName);
```

`windll` does not try to select one of them by magic, you must access the version you need by specifying `GetModuleHandleA` or `GetModuleHandleW` explicitly, and then call it with strings or unicode strings respectively.

Sometimes, dlls export functions with names which aren't valid Python identifiers, like `"??2@YAPAXI@Z"`. In this case you have to use `getattr()` to retrieve the function:

```
>>> getattr(cdll.msvcrt, "??2@YAPAXI@Z")
<_FuncPtr object at 0x...>
>>>
```

On Windows, some dlls export functions not by name but by ordinal. These functions can be accessed by indexing the dll object with the ordinal number:

```
>>> cdll.kernel32[1]
<_FuncPtr object at 0x...>
>>> cdll.kernel32[0]
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "ctypes.py", line 310, in __getitem__
    func = _StdcallFuncPtr(name, self)
AttributeError: function ordinal 0 not found
>>>
```

### Calling functions

You can call these functions like any other Python callable. This example uses the `time()` function, which returns system time in seconds since the Unix epoch, and the `GetModuleHandleA()` function, which returns a win32 module handle.

This example calls both functions with a NULL pointer (None should be used as the NULL pointer):

```
>>> print libc.time(None)
1150640792
>>> print hex(windll.kernel32.GetModuleHandleA(None))
0x1d000000
>>>
```

`ctypes` tries to protect you from calling functions with the wrong number of arguments or the wrong calling convention. Unfortunately this only works on Windows. It does this by examining the stack after the function returns, so although an error is raised the function *has* been called:

```
>>> windll.kernel32.GetModuleHandleA()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with not enough arguments (4 bytes missing)
>>> windll.kernel32.GetModuleHandleA(0, 0)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with too many arguments (4 bytes in excess)
>>>
```

The same exception is raised when you call an `stdcall` function with the `cdecl` calling convention, or vice versa:

```
>>> cdll.kernel32.GetModuleHandleA(None)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with not enough arguments (4 bytes missing)
>>>

>>> windll.msvcrt.printf("spam")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with too many arguments (4 bytes in excess)
>>>
```

To find out the correct calling convention you have to look into the C header file or the documentation for the function you want to call.

On Windows, `ctypes` uses win32 structured exception handling to prevent crashes from general protection faults when functions are called with invalid argument values:

```
>>> windll.kernel32.GetModuleHandleA(32)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
```

```
WindowsError: exception: access violation reading 0x00000020
>>>
```

There are, however, enough ways to crash Python with `ctypes`, so you should be careful anyway.

None, integers, longs, byte strings and unicode strings are the only native Python objects that can directly be used as parameters in these function calls. None is passed as a C NULL pointer, byte strings and unicode strings are passed as pointer to the memory block that contains their data (`char *` or `wchar_t *`). Python integers and Python longs are passed as the platforms default C `int` type, their value is masked to fit into the C type.

Before we move on calling functions with other parameter types, we have to learn more about `ctypes` data types.

## Fundamental data types

`ctypes` defines a number of primitive C compatible data types :

ctypes type	C type	Python type
<code>c_bool</code>	<code>_Bool</code>	bool (1)
<code>c_char</code>	<code>char</code>	1-character string
<code>c_wchar</code>	<code>wchar_t</code>	1-character unicode string
<code>c_byte</code>	<code>char</code>	int/long
<code>c_ubyte</code>	unsigned char	int/long
<code>c_short</code>	short	int/long
<code>c_ushort</code>	unsigned short	int/long
<code>c_int</code>	int	int/long
<code>c_uint</code>	unsigned int	int/long
<code>c_long</code>	long	int/long
<code>c_ulong</code>	unsigned long	int/long
<code>c_longlong</code>	<code>__int64</code> or long long	int/long
<code>c_ulonglong</code>	unsigned <code>__int64</code> or unsigned long long	int/long
<code>c_float</code>	float	float
<code>c_double</code>	double	float
<code>c_longdouble</code>	long double	float
<code>c_char_p</code>	<code>char *</code> (NUL terminated)	string or None
<code>c_wchar_p</code>	<code>wchar_t *</code> (NUL terminated)	unicode or None
<code>c_void_p</code>	<code>void *</code>	int/long or None

1. The constructor accepts any object with a truth value.

All these types can be created by calling them with an optional initializer of the correct type and value:

```
>>> c_int()
c_long(0)
>>> c_char_p("Hello, World")
c_char_p('Hello, World')
>>> c_ushort(-3)
c_ushort(65533)
>>>
```

Since these types are mutable, their value can also be changed afterwards:

```
>>> i = c_int(42)
>>> print i
c_long(42)
>>> print i.value
42
>>> i.value = -99
>>> print i.value
```

```
-99
>>>
```

Assigning a new value to instances of the pointer types `c_char_p`, `c_wchar_p`, and `c_void_p` changes the *memory location* they point to, *not the contents* of the memory block (of course not, because Python strings are immutable):

```
>>> s = "Hello, World"
>>> c_s = c_char_p(s)
>>> print c_s
c_char_p('Hello, World')
>>> c_s.value = "Hi, there"
>>> print c_s
c_char_p('Hi, there')
>>> print s           # first string is unchanged
Hello, World
>>>
```

You should be careful, however, not to pass them to functions expecting pointers to mutable memory. If you need mutable memory blocks, ctypes has a `create_string_buffer()` function which creates these in various ways. The current memory block contents can be accessed (or changed) with the `raw` property; if you want to access it as NUL terminated string, use the `value` property:

```
>>> from ctypes import *
>>> p = create_string_buffer(3)           # create a 3 byte buffer, initialized to NUL bytes
>>> print sizeof(p), repr(p.raw)
3 '\x00\x00\x00'
>>> p = create_string_buffer("Hello")    # create a buffer containing a NUL terminated string
>>> print sizeof(p), repr(p.raw)
6 'Hello\x00'
>>> print repr(p.value)
'Hello'
>>> p = create_string_buffer("Hello", 10) # create a 10 byte buffer
>>> print sizeof(p), repr(p.raw)
10 'Hello\x00\x00\x00\x00\x00\x00'
>>> p.value = "Hi"
>>> print sizeof(p), repr(p.raw)
10 'Hi\x00lo\x00\x00\x00\x00\x00'
>>>
```

The `create_string_buffer()` function replaces the `c_buffer()` function (which is still available as an alias), as well as the `c_string()` function from earlier ctypes releases. To create a mutable memory block containing unicode characters of the C type `wchar_t` use the `create_unicode_buffer()` function.

## Calling functions, continued

Note that `printf` prints to the real standard output channel, *not* to `sys.stdout`, so these examples will only work at the console prompt, not from within *IDLE* or *PythonWin*:

```
>>> printf = libc.printf
>>> printf("Hello, %s\n", "World!")
Hello, World!
14
>>> printf("Hello, %S\n", u"World!")
Hello, World!
14
```

```
>>> printf("%d bottles of beer\n", 42)
42 bottles of beer
19
>>> printf("%f bottles of beer\n", 42.5)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ArgumentError: argument 2: exceptions.TypeError: Don't know how to convert parameter 2
>>>
```

As has been mentioned before, all Python types except integers, strings, and unicode strings have to be wrapped in their corresponding `ctypes` type, so that they can be converted to the required C data type:

```
>>> printf("An int %d, a double %f\n", 1234, ctypes.double(3.14))
An int 1234, a double 3.140000
31
>>>
```

### Calling functions with your own custom data types

You can also customize `ctypes` argument conversion to allow instances of your own classes be used as function arguments. `ctypes` looks for an `_as_parameter_` attribute and uses this as the function argument. Of course, it must be one of integer, string, or unicode:

```
>>> class Bottles(object):
...     def __init__(self, number):
...         self._as_parameter_ = number
...
>>> bottles = Bottles(42)
>>> printf("%d bottles of beer\n", bottles)
42 bottles of beer
19
>>>
```

If you don't want to store the instance's data in the `_as_parameter_` instance variable, you could define a `property()` which makes the data available.

### Specifying the required argument types (function prototypes)

It is possible to specify the required argument types of functions exported from DLLs by setting the `argtypes` attribute.

`argtypes` must be a sequence of C data types (the `printf` function is probably not a good example here, because it takes a variable number and different types of parameters depending on the format string, on the other hand this is quite handy to experiment with this feature):

```
>>> printf.argtypes = [c_char_p, c_char_p, c_int, ctypes.double]
>>> printf("String '%s', Int %d, Double %f\n", "Hi", 10, 2.2)
String 'Hi', Int 10, Double 2.200000
37
>>>
```

Specifying a format protects against incompatible argument types (just as a prototype for a C function), and tries to convert the arguments to valid types:

```
>>> printf("%d %d %d", 1, 2, 3)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
```

```
ArgumentError: argument 2: exceptions.TypeError: wrong type
>>> printf("%s %d %f\n", "X", 2, 3)
X 2 3.000000
13
>>>
```

If you have defined your own classes which you pass to function calls, you have to implement a `from_param()` class method for them to be able to use them in the `argtypes` sequence. The `from_param()` class method receives the Python object passed to the function call, it should do a typecheck or whatever is needed to make sure this object is acceptable, and then return the object itself, its `_as_parameter_` attribute, or whatever you want to pass as the C function argument in this case. Again, the result should be an integer, string, unicode, a `ctypes` instance, or an object with an `_as_parameter_` attribute.

## Return types

By default functions are assumed to return the C `int` type. Other return types can be specified by setting the `restype` attribute of the function object.

Here is a more advanced example, it uses the `strchr` function, which expects a string pointer and a char, and returns a pointer to a string:

```
>>> strchr = libc.strchr
>>> strchr("abcdef", ord("d"))
8059983
>>> strchr.restype = c_char_p # c_char_p is a pointer to a string
>>> strchr("abcdef", ord("d"))
'def'
>>> print strchr("abcdef", ord("x"))
None
>>>
```

If you want to avoid the `ord("x")` calls above, you can set the `argtypes` attribute, and the second argument will be converted from a single character Python string into a C char:

```
>>> strchr.restype = c_char_p
>>> strchr.argtypes = [c_char_p, c_char]
>>> strchr("abcdef", "d")
'def'
>>> strchr("abcdef", "def")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ArgumentError: argument 2: exceptions.TypeError: one character string expected
>>> print strchr("abcdef", "x")
None
>>> strchr("abcdef", "d")
'def'
>>>
```

You can also use a callable Python object (a function or a class for example) as the `restype` attribute, if the foreign function returns an integer. The callable will be called with the *integer* the C function returns, and the result of this call will be used as the result of your function call. This is useful to check for error return values and automatically raise an exception:

```
>>> GetModuleHandle = windll.kernel32.GetModuleHandleA
>>> def ValidHandle(value):
...     if value == 0:
...         raise WinError()
... 
```

```

...     return value
...
>>>
>>> GetModuleHandle.restype = ValidHandle
>>> GetModuleHandle(None)
486539264
>>> GetModuleHandle("something silly")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 3, in ValidHandle
WindowsError: [Errno 126] The specified module could not be found.
>>>

```

WinError is a function which will call Windows FormatMessage() api to get the string representation of an error code, and *returns* an exception. WinError takes an optional error code parameter, if no one is used, it calls GetLastError() to retrieve it.

Please note that a much more powerful error checking mechanism is available through the `errcheck` attribute; see the reference manual for details.

### Passing pointers (or: passing parameters by reference)

Sometimes a C api function expects a *pointer* to a data type as parameter, probably to write into the corresponding location, or if the data is too large to be passed by value. This is also known as *passing parameters by reference*.

`ctypes` exports the `byref()` function which is used to pass parameters by reference. The same effect can be achieved with the `pointer()` function, although `pointer()` does a lot more work since it constructs a real pointer object, so it is faster to use `byref()` if you don't need the pointer object in Python itself:

```

>>> i = c_int()
>>> f = c_float()
>>> s = create_string_buffer('\000' * 32)
>>> print i.value, f.value, repr(s.value)
0 0.0 ''
>>> libc.sscanf("1 3.14 Hello", "%d %f %s",
...             byref(i), byref(f), s)
3
>>> print i.value, f.value, repr(s.value)
1 3.1400001049 'Hello'
>>>

```

### Structures and unions

Structures and unions must derive from the `Structure` and `Union` base classes which are defined in the `ctypes` module. Each subclass must define a `_fields_` attribute. `_fields_` must be a list of *2-tuples*, containing a *field name* and a *field type*.

The field type must be a `ctypes` type like `c_int`, or any other derived `ctypes` type: structure, union, array, pointer.

Here is a simple example of a POINT structure, which contains two integers named *x* and *y*, and also shows how to initialize a structure in the constructor:

```

>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = [("x", c_int),
...                 ("y", c_int)]

```

```
...
>>> point = POINT(10, 20)
>>> print point.x, point.y
10 20
>>> point = POINT(y=5)
>>> print point.x, point.y
0 5
>>> POINT(1, 2, 3)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: too many initializers
>>>
```

You can, however, build much more complicated structures. Structures can itself contain other structures by using a structure as a field type.

Here is a RECT structure which contains two POINTs named *upperleft* and *lowerright*:

```
>>> class RECT(Structure):
...     _fields_ = [("upperleft", POINT),
...                 ("lowerright", POINT)]
...
>>> rc = RECT(point)
>>> print rc.upperleft.x, rc.upperleft.y
0 5
>>> print rc.lowerright.x, rc.lowerright.y
0 0
>>>
```

Nested structures can also be initialized in the constructor in several ways:

```
>>> r = RECT(POINT(1, 2), POINT(3, 4))
>>> r = RECT((1, 2), (3, 4))
```

Field *descriptors* can be retrieved from the *class*, they are useful for debugging because they can provide useful information:

```
>>> print POINT.x
<Field type=c_long, ofs=0, size=4>
>>> print POINT.y
<Field type=c_long, ofs=4, size=4>
>>>
```

### Structure/union alignment and byte order

By default, Structure and Union fields are aligned in the same way the C compiler does it. It is possible to override this behavior by specifying a `_pack_` class attribute in the subclass definition. This must be set to a positive integer and specifies the maximum alignment for the fields. This is what `#pragma pack(n)` also does in MSVC.

`ctypes` uses the native byte order for Structures and Unions. To build structures with non-native byte order, you can use one of the `BigEndianStructure`, `LittleEndianStructure`, `BigEndianUnion`, and `LittleEndianUnion` base classes. These classes cannot contain pointer fields.

### Bit fields in structures and unions

It is possible to create structures and unions containing bit fields. Bit fields are only possible for integer fields, the bit width is specified as the third item in the `_fields_` tuples:

```

>>> class Int(Structure):
...     _fields_ = [("first_16", c_int, 16),
...                 ("second_16", c_int, 16)]
...
>>> print Int.first_16
<Field type=c_long, ofs=0:0, bits=16>
>>> print Int.second_16
<Field type=c_long, ofs=0:16, bits=16>
>>>

```

## Arrays

Arrays are sequences, containing a fixed number of instances of the same type.

The recommended way to create array types is by multiplying a data type with a positive integer:

```
TenPointsArrayType = POINT * 10
```

Here is an example of an somewhat artificial data type, a structure containing 4 POINTs among other stuff:

```

>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = ("x", c_int), ("y", c_int)
...
>>> class MyStruct(Structure):
...     _fields_ = [("a", c_int),
...                 ("b", c_float),
...                 ("point_array", POINT * 4)]
>>>
>>> print len(MyStruct().point_array)
4
>>>

```

Instances are created in the usual way, by calling the class:

```

arr = TenPointsArrayType()
for pt in arr:
    print pt.x, pt.y

```

The above code print a series of 0 0 lines, because the array contents is initialized to zeros.

Initializers of the correct type can also be specified:

```

>>> from ctypes import *
>>> TenIntegers = c_int * 10
>>> ii = TenIntegers(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
>>> print ii
<c_long_Array_10 object at 0x...>
>>> for i in ii: print i,
...
1 2 3 4 5 6 7 8 9 10
>>>

```

## Pointers

Pointer instances are created by calling the `pointer()` function on a `ctypes` type:

```
>>> from ctypes import *
>>> i = c_int(42)
>>> pi = pointer(i)
>>>
```

Pointer instances have a `contents` attribute which returns the object to which the pointer points, the `i` object above:

```
>>> pi.contents
c_long(42)
>>>
```

Note that `ctypes` does not have OOR (original object return), it constructs a new, equivalent object each time you retrieve an attribute:

```
>>> pi.contents is i
False
>>> pi.contents is pi.contents
False
>>>
```

Assigning another `c_int` instance to the pointer's `contents` attribute would cause the pointer to point to the memory location where this is stored:

```
>>> i = c_int(99)
>>> pi.contents = i
>>> pi.contents
c_long(99)
>>>
```

Pointer instances can also be indexed with integers:

```
>>> pi[0]
99
>>>
```

Assigning to an integer index changes the pointed to value:

```
>>> print i
c_long(99)
>>> pi[0] = 22
>>> print i
c_long(22)
>>>
```

It is also possible to use indexes different from 0, but you must know what you're doing, just as in C: You can access or change arbitrary memory locations. Generally you only use this feature if you receive a pointer from a C function, and you *know* that the pointer actually points to an array instead of a single item.

Behind the scenes, the `pointer()` function does more than simply create pointer instances, it has to create pointer *types* first. This is done with the `POINTER()` function, which accepts any `ctypes` type, and returns a new type:

```
>>> PI = POINTER(c_int)
>>> PI
<class 'ctypes.LP_c_long'>
>>> PI(42)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: expected c_long instead of int
>>> PI(c_int(42))
```

```
<ctypes.LP_c_long object at 0x...>
>>>
```

Calling the pointer type without an argument creates a NULL pointer. NULL pointers have a `False` boolean value:

```
>>> null_ptr = POINTER(c_int)()
>>> print bool(null_ptr)
False
>>>
```

`ctypes` checks for NULL when dereferencing pointers (but dereferencing invalid non-NULL pointers would crash Python):

```
>>> null_ptr[0]
Traceback (most recent call last):
....
ValueError: NULL pointer access
>>>
```

```
>>> null_ptr[0] = 1234
Traceback (most recent call last):
....
ValueError: NULL pointer access
>>>
```

## Type conversions

Usually, `ctypes` does strict type checking. This means, if you have `POINTER(c_int)` in the `argtypes` list of a function or as the type of a member field in a structure definition, only instances of exactly the same type are accepted. There are some exceptions to this rule, where `ctypes` accepts other objects. For example, you can pass compatible array instances instead of pointer types. So, for `POINTER(c_int)`, `ctypes` accepts an array of `c_int`:

```
>>> class Bar(Structure):
...     _fields_ = [("count", c_int), ("values", POINTER(c_int))]
...
>>> bar = Bar()
>>> bar.values = (c_int * 3)(1, 2, 3)
>>> bar.count = 3
>>> for i in range(bar.count):
...     print bar.values[i]
...
1
2
3
>>>
```

To set a `POINTER` type field to NULL, you can assign `None`:

```
>>> bar.values = None
>>>
```

Sometimes you have instances of incompatible types. In C, you can cast one type into another type. `ctypes` provides a `cast()` function which can be used in the same way. The `Bar` structure defined above accepts `POINTER(c_int)` pointers or `c_int` arrays for its `values` field, but not instances of other types:

```
>>> bar.values = (c_byte * 4)()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
```

**TypeError:** incompatible types, c\_byte\_Array\_4 instance instead of LP\_c\_long instance  
>>>

For these cases, the `cast()` function is handy.

The `cast()` function can be used to cast a ctypes instance into a pointer to a different ctypes data type. `cast()` takes two parameters, a ctypes object that is or can be converted to a pointer of some kind, and a ctypes pointer type. It returns an instance of the second argument, which references the same memory block as the first argument:

```
>>> a = (c_byte * 4)()
>>> cast(a, POINTER(c_int))
<ctypes.LP_c_long object at ...>
>>>
```

So, `cast()` can be used to assign to the values field of Bar the structure:

```
>>> bar = Bar()
>>> bar.values = cast((c_byte * 4)(), POINTER(c_int))
>>> print bar.values[0]
0
>>>
```

### Incomplete Types

*Incomplete Types* are structures, unions or arrays whose members are not yet specified. In C, they are specified by forward declarations, which are defined later:

```
struct cell; /* forward declaration */

struct cell {
    char *name;
    struct cell *next;
};
```

The straightforward translation into ctypes code would be this, but it does not work:

```
>>> class cell(Structure):
...     _fields_ = [("name", c_char_p),
...                 ("next", POINTER(cell))]
...
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 2, in cell
NameError: name 'cell' is not defined
>>>
```

because the new class `cell` is not available in the class statement itself. In `ctypes`, we can define the `cell` class and set the `_fields_` attribute later, after the class statement:

```
>>> from ctypes import *
>>> class cell(Structure):
...     pass
...
>>> cell._fields_ = [("name", c_char_p),
...                  ("next", POINTER(cell))]
>>>
```

Lets try it. We create two instances of `cell`, and let them point to each other, and finally follow the pointer chain a few times:

```

>>> c1 = cell()
>>> c1.name = "foo"
>>> c2 = cell()
>>> c2.name = "bar"
>>> c1.next = pointer(c2)
>>> c2.next = pointer(c1)
>>> p = c1
>>> for i in range(8):
...     print p.name,
...     p = p.next[0]
...
foo bar foo bar foo bar foo bar
>>>

```

## Callback functions

`ctypes` allows to create C callable function pointers from Python callables. These are sometimes called *callback functions*.

First, you must create a class for the callback function, the class knows the calling convention, the return type, and the number and types of arguments this function will receive.

The `CFUNCTYPE` factory function creates types for callback functions using the normal `cdecl` calling convention, and, on Windows, the `WINFUNCTYPE` factory function creates types for callback functions using the `stdcall` calling convention.

Both of these factory functions are called with the result type as first argument, and the callback functions expected argument types as the remaining arguments.

I will present an example here which uses the standard C library's `qsort()` function, this is used to sort items with the help of a callback function. `qsort()` will be used to sort an array of integers:

```

>>> IntArray5 = c_int * 5
>>> ia = IntArray5(5, 1, 7, 33, 99)
>>> qsort = libc.qsort
>>> qsort.restype = None
>>>

```

`qsort()` must be called with a pointer to the data to sort, the number of items in the data array, the size of one item, and a pointer to the comparison function, the callback. The callback will then be called with two pointers to items, and it must return a negative integer if the first item is smaller than the second, a zero if they are equal, and a positive integer else.

So our callback function receives pointers to integers, and must return an integer. First we create the `type` for the callback function:

```

>>> CMPFUNC = CFUNCTYPE(c_int, POINTER(c_int), POINTER(c_int))
>>>

```

For the first implementation of the callback function, we simply print the arguments we get, and return 0 (incremental development ;-):

```

>>> def py_cmp_func(a, b):
...     print "py_cmp_func", a, b
...     return 0
...
>>>

```

Create the C callable callback:



Final run on Windows:

```
>>> qsort(ia, len(ia), sizeof(c_int), CMPFUNC(py_cmp_func))
py_cmp_func 33 7
py_cmp_func 99 33
py_cmp_func 5 99
py_cmp_func 1 99
py_cmp_func 33 7
py_cmp_func 1 33
py_cmp_func 5 33
py_cmp_func 5 7
py_cmp_func 1 7
py_cmp_func 5 1
>>>
```

and on Linux:

```
>>> qsort(ia, len(ia), sizeof(c_int), CMPFUNC(py_cmp_func))
py_cmp_func 5 1
py_cmp_func 33 99
py_cmp_func 7 33
py_cmp_func 1 7
py_cmp_func 5 7
>>>
```

It is quite interesting to see that the Windows `qsort()` function needs more comparisons than the linux version!

As we can easily check, our array is sorted now:

```
>>> for i in ia: print i,
...
1 5 7 33 99
>>>
```

### Important note for callback functions:

Make sure you keep references to `CFUNCTYPE` objects as long as they are used from C code. `ctypes` doesn't, and if you don't, they may be garbage collected, crashing your program when a callback is made.

### Accessing values exported from dlls

Some shared libraries not only export functions, they also export variables. An example in the Python library itself is the `Py_OptimizeFlag`, an integer set to 0, 1, or 2, depending on the `-O` or `-OO` flag given on startup.

`ctypes` can access values like this with the `in_dll()` class methods of the type. `pythonapi` is a predefined symbol giving access to the Python C api:

```
>>> opt_flag = c_int.in_dll(pythonapi, "Py_OptimizeFlag")
>>> print opt_flag
c_long(0)
>>>
```

If the interpreter would have been started with `-O`, the sample would have printed `c_long(1)`, or `c_long(2)` if `-OO` would have been specified.

An extended example which also demonstrates the use of pointers accesses the `PyImport_FrozenModules` pointer exported by Python.

Quoting the Python docs: *This pointer is initialized to point to an array of “struct\_frozen” records, terminated by one whose members are all NULL or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.*

So manipulating this pointer could even prove useful. To restrict the example size, we show only how this table can be read with `ctypes`:

```
>>> from ctypes import *
>>>
>>> class struct_frozen(Structure):
...     _fields_ = [("name", c_char_p),
...                 ("code", POINTER(c_ubyte)),
...                 ("size", c_int)]
...
>>>
```

We have defined the struct `_frozen` data type, so we can get the pointer to the table:

```
>>> FrozenTable = POINTER(struct_frozen)
>>> table = FrozenTable.in_dll(pythonapi, "PyImport_FrozenModules")
>>>
```

Since `table` is a pointer to the array of `struct_frozen` records, we can iterate over it, but we just have to make sure that our loop terminates, because pointers have no size. Sooner or later it would probably crash with an access violation or whatever, so it's better to break out of the loop when we hit the NULL entry:

```
>>> for item in table:
...     print item.name, item.size
...     if item.name is None:
...         break
...
__hello__ 104
__phello__ -104
__phello__.spam 104
None 0
>>>
```

The fact that standard Python has a frozen module and a frozen package (indicated by the negative size member) is not well known, it is only used for testing. Try it out with `import __hello__` for example.

## Surprises

There are some edges in `ctypes` where you may expect something else than what actually happens.

Consider the following example:

```
>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = ("x", c_int), ("y", c_int)
...
>>> class RECT(Structure):
...     _fields_ = ("a", POINT), ("b", POINT)
...
>>> p1 = POINT(1, 2)
>>> p2 = POINT(3, 4)
>>> rc = RECT(p1, p2)
>>> print rc.a.x, rc.a.y, rc.b.x, rc.b.y
1 2 3 4
```

```
>>> # now swap the two points
>>> rc.a, rc.b = rc.b, rc.a
>>> print rc.a.x, rc.a.y, rc.b.x, rc.b.y
3 4 3 4
>>>
```

Hm. We certainly expected the last statement to print 3 4 1 2. What happened? Here are the steps of the `rc.a, rc.b = rc.b, rc.a` line above:

```
>>> temp0, temp1 = rc.b, rc.a
>>> rc.a = temp0
>>> rc.b = temp1
>>>
```

Note that `temp0` and `temp1` are objects still using the internal buffer of the `rc` object above. So executing `rc.a = temp0` copies the buffer contents of `temp0` into `rc`'s buffer. This, in turn, changes the contents of `temp1`. So, the last assignment `rc.b = temp1`, doesn't have the expected effect.

Keep in mind that retrieving sub-objects from Structure, Unions, and Arrays doesn't *copy* the sub-object, instead it retrieves a wrapper object accessing the root-object's underlying buffer.

Another example that may behave different from what one would expect is this:

```
>>> s = c_char_p()
>>> s.value = "abc def ghi"
>>> s.value
'abc def ghi'
>>> s.value is s.value
False
>>>
```

Why is it printing `False`? `ctypes` instances are objects containing a memory block plus some *descriptors* accessing the contents of the memory. Storing a Python object in the memory block does not store the object itself, instead the contents of the object is stored. Accessing the contents again constructs a new Python object each time!

## Variable-sized data types

`ctypes` provides some support for variable-sized arrays and structures.

The `resize()` function can be used to resize the memory buffer of an existing `ctypes` object. The function takes the object as first argument, and the requested size in bytes as the second argument. The memory block cannot be made smaller than the natural memory block specified by the objects type, a `ValueError` is raised if this is tried:

```
>>> short_array = (c_short * 4)()
>>> print sizeof(short_array)
8
>>> resize(short_array, 4)
Traceback (most recent call last):
...
ValueError: minimum size is 8
>>> resize(short_array, 32)
>>> sizeof(short_array)
32
>>> sizeof(type(short_array))
8
>>>
```

This is nice and fine, but how would one access the additional elements contained in this array? Since the type still only knows about 4 elements, we get errors accessing other elements:

```
>>> short_array[:]
[0, 0, 0, 0]
>>> short_array[7]
Traceback (most recent call last):
...
IndexError: invalid index
>>>
```

Another way to use variable-sized data types with `ctypes` is to use the dynamic nature of Python, and (re-)define the data type after the required size is already known, on a case by case basis.

### 15.17.2 ctypes reference

#### Finding shared libraries

When programming in a compiled language, shared libraries are accessed when compiling/linking a program, and when the program is run.

The purpose of the `find_library()` function is to locate a library in a way similar to what the compiler does (on platforms with several versions of a shared library the most recent should be loaded), while the `ctypes` library loaders act like when a program is run, and call the runtime loader directly.

The `ctypes.util` module provides a function which can help to determine the library to load.

`ctypes.util.find_library(name)`

Try to find a library and return a pathname. *name* is the library name without any prefix like *lib*, suffix like *.so*, *.dylib* or version number (this is the form used for the posix linker option *-l*). If no library can be found, returns `None`.

The exact functionality is system dependent.

On Linux, `find_library()` tries to run external programs (`/sbin/ldconfig`, `gcc`, and `objdump`) to find the library file. It returns the filename of the library file. Here are some examples:

```
>>> from ctypes.util import find_library
>>> find_library("m")
'libm.so.6'
>>> find_library("c")
'libc.so.6'
>>> find_library("bz2")
'libbz2.so.1.0'
>>>
```

On OS X, `find_library()` tries several predefined naming schemes and paths to locate the library, and returns a full pathname if successful:

```
>>> from ctypes.util import find_library
>>> find_library("c")
'/usr/lib/libc.dylib'
>>> find_library("m")
'/usr/lib/libm.dylib'
>>> find_library("bz2")
'/usr/lib/libbz2.dylib'
>>> find_library("AGL")
```

```
'/System/Library/Frameworks/AGL.framework/AGL'
>>>
```

On Windows, `find_library()` searches along the system search path, and returns the full pathname, but since there is no predefined naming scheme a call like `find_library("c")` will fail and return `None`.

If wrapping a shared library with `ctypes`, it *may* be better to determine the shared library name at development type, and hardcode that into the wrapper module instead of using `find_library()` to locate the library at runtime.

## Loading shared libraries

There are several ways to loaded shared libraries into the Python process. One way is to instantiate one of the following classes:

```
class ctypes.CDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False,
                  use_last_error=False)
```

Instances of this class represent loaded shared libraries. Functions in these libraries use the standard C calling convention, and are assumed to return `int`.

```
class ctypes.OleDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False,
                   use_last_error=False)
```

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the `stdcall` calling convention, and are assumed to return the windows specific `HRESULT` code. `HRESULT` values contain information specifying whether the function call failed or succeeded, together with additional error code. If the return value signals a failure, an `WindowsError` is automatically raised.

```
class ctypes.WinDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False,
                   use_last_error=False)
```

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the `stdcall` calling convention, and are assumed to return `int` by default.

On Windows CE only the standard calling convention is used, for convenience the `WinDLL` and `OleDLL` use the standard calling convention on this platform.

The Python *global interpreter lock* is released before calling any function exported by these libraries, and reacquired afterwards.

```
class ctypes.PyDLL(name, mode=DEFAULT_MODE, handle=None)
```

Instances of this class behave like `CDLL` instances, except that the Python GIL is *not* released during the function call, and after the function execution the Python error flag is checked. If the error flag is set, a Python exception is raised.

Thus, this is only useful to call Python C api functions directly.

All these classes can be instantiated by calling them with at least one argument, the pathname of the shared library. If you have an existing handle to an already loaded shared library, it can be passed as the `handle` named parameter, otherwise the underlying platforms `dlopen` or `LoadLibrary` function is used to load the library into the process, and to get a handle to it.

The `mode` parameter can be used to specify how the library is loaded. For details, consult the `dlopen(3)` manpage, on Windows, `mode` is ignored.

The `use_errno` parameter, when set to `True`, enables a `ctypes` mechanism that allows to access the system `errno` error number in a safe way. `ctypes` maintains a thread-local copy of the systems `errno` variable; if you call foreign functions created with `use_errno=True` then the `errno` value before the function call is swapped with the `ctypes` private copy, the same happens immediately after the function call.

The function `ctypes.get_errno()` returns the value of the `ctypes` private copy, and the function `ctypes.set_errno()` changes the `ctypes` private copy to a new value and returns the former value.

The `use_last_error` parameter, when set to `True`, enables the same mechanism for the Windows error code which is managed by the `GetLastError()` and `SetLastError()` Windows API functions; `ctypes.get_last_error()` and `ctypes.set_last_error()` are used to request and change the ctypes private copy of the windows error code. New in version 2.6: The `use_last_error` and `use_errno` optional parameters were added.

`ctypes.RTLD_GLOBAL`

Flag to use as `mode` parameter. On platforms where this flag is not available, it is defined as the integer zero.

`ctypes.RTLD_LOCAL`

Flag to use as `mode` parameter. On platforms where this is not available, it is the same as `RTLD_GLOBAL`.

`ctypes.DEFAULT_MODE`

The default mode which is used to load shared libraries. On OSX 10.3, this is `RTLD_GLOBAL`, otherwise it is the same as `RTLD_LOCAL`.

Instances of these classes have no public methods, however `__getattr__()` and `__getitem__()` have special behavior: functions exported by the shared library can be accessed as attributes of by index. Please note that both `__getattr__()` and `__getitem__()` cache their result, so calling them repeatedly returns the same object each time.

The following public attributes are available, their name starts with an underscore to not clash with exported function names:

`PyDLL._handle`

The system handle used to access the library.

`PyDLL._name`

The name of the library passed in the constructor.

Shared libraries can also be loaded by using one of the prefabricated objects, which are instances of the `LibraryLoader` class, either by calling the `LoadLibrary()` method, or by retrieving the library as attribute of the loader instance.

**class** `ctypes.LibraryLoader` (*dlltype*)

Class which loads shared libraries. *dlltype* should be one of the `CDLL`, `PyDLL`, `WinDLL`, or `OleDLL` types.

`__getattr__()` has special behavior: It allows to load a shared library by accessing it as attribute of a library loader instance. The result is cached, so repeated attribute accesses return the same library each time.

**LoadLibrary** (*name*)

Load a shared library into the process and return it. This method always returns a new instance of the library.

These prefabricated library loaders are available:

`ctypes.cdll`

Creates `CDLL` instances.

`ctypes.windll`

Windows only: Creates `WinDLL` instances.

`ctypes.oledll`

Windows only: Creates `OleDLL` instances.

`ctypes.pydll`

Creates `PyDLL` instances.

For accessing the C Python api directly, a ready-to-use Python shared library object is available:

`ctypes.pythonapi`

An instance of `PyDLL` that exposes Python C API functions as attributes. Note that all these functions are

assumed to return `C int`, which is of course not always the truth, so you have to assign the correct `restype` attribute to use these functions.

## Foreign functions

As explained in the previous section, foreign functions can be accessed as attributes of loaded shared libraries. The function objects created in this way by default accept any number of arguments, accept any ctypes data instances as arguments, and return the default result type specified by the library loader. They are instances of a private class:

**class** `ctypes._FuncPtr`

Base class for C callable foreign functions.

Instances of foreign functions are also C compatible data types; they represent C function pointers.

This behavior can be customized by assigning to special attributes of the foreign function object.

### **restype**

Assign a ctypes type to specify the result type of the foreign function. Use `None` for `void`, a function not returning anything.

It is possible to assign a callable Python object that is not a ctypes type, in this case the function is assumed to return a `C int`, and the callable will be called with this integer, allowing to do further processing or error checking. Using this is deprecated, for more flexible post processing or error checking use a ctypes data type as `restype` and assign a callable to the `errcheck` attribute.

### **argtypes**

Assign a tuple of ctypes types to specify the argument types that the function accepts. Functions using the `stdcall` calling convention can only be called with the same number of arguments as the length of this tuple; functions using the C calling convention accept additional, unspecified arguments as well.

When a foreign function is called, each actual argument is passed to the `from_param()` class method of the items in the `argtypes` tuple, this method allows to adapt the actual argument to an object that the foreign function accepts. For example, a `c_char_p` item in the `argtypes` tuple will convert a unicode string passed as argument into an byte string using ctypes conversion rules.

New: It is now possible to put items in `argtypes` which are not ctypes types, but each item must have a `from_param()` method which returns a value usable as argument (integer, string, ctypes instance). This allows to define adapters that can adapt custom objects as function parameters.

### **errcheck**

Assign a Python function or another callable to this attribute. The callable will be called with three or more arguments:

**callable** (*result, func, arguments*)

*result* is what the foreign function returns, as specified by the `restype` attribute.

*func* is the foreign function object itself, this allows to reuse the same callable object to check or post process the results of several functions.

*arguments* is a tuple containing the parameters originally passed to the function call, this allows to specialize the behavior on the arguments used.

The object that this function returns will be returned from the foreign function call, but it can also check the result value and raise an exception if the foreign function call failed.

**exception** `ctypes.ArgumentError`

This exception is raised when a foreign function call cannot convert one of the passed arguments.

## Function prototypes

Foreign functions can also be created by instantiating function prototypes. Function prototypes are similar to function prototypes in C; they describe a function (return type, argument types, calling convention) without defining an implementation. The factory functions must be called with the desired result type and the argument types of the function.

`ctypes.CFUNCTYPE` (*restype*, \**argtypes*, *use\_errno*=False, *use\_last\_error*=False)

The returned function prototype creates functions that use the standard C calling convention. The function will release the GIL during the call. If *use\_errno* is set to True, the ctypes private copy of the system `errno` variable is exchanged with the real `errno` value before and after the call; *use\_last\_error* does the same for the Windows error code. Changed in version 2.6: The optional *use\_errno* and *use\_last\_error* parameters were added.

`ctypes.WINFUNCTYPE` (*restype*, \**argtypes*, *use\_errno*=False, *use\_last\_error*=False)

Windows only: The returned function prototype creates functions that use the `stdcall` calling convention, except on Windows CE where `WINFUNCTYPE()` is the same as `CFUNCTYPE()`. The function will release the GIL during the call. *use\_errno* and *use\_last\_error* have the same meaning as above.

`ctypes.PYFUNCTYPE` (*restype*, \**argtypes*)

The returned function prototype creates functions that use the Python calling convention. The function will *not* release the GIL during the call.

Function prototypes created by these factory functions can be instantiated in different ways, depending on the type and number of the parameters in the call:

**prototype** (*address*)

Returns a foreign function at the specified address which must be an integer.

**prototype** (*callable*)

Create a C callable function (a callback function) from a Python *callable*.

**prototype** (*func\_spec*[, *paramflags* ])

Returns a foreign function exported by a shared library. *func\_spec* must be a 2-tuple (*name\_or\_ordinal*, *library*). The first item is the name of the exported function as string, or the ordinal of the exported function as small integer. The second item is the shared library instance.

**prototype** (*vtbl\_index*, *name* [, *paramflags* [, *iid* ] ])

Returns a foreign function that will call a COM method. *vtbl\_index* is the index into the virtual function table, a small non-negative integer. *name* is name of the COM method. *iid* is an optional pointer to the interface identifier which is used in extended error reporting.

COM methods use a special calling convention: They require a pointer to the COM interface as first argument, in addition to those parameters that are specified in the *argtypes* tuple.

The optional *paramflags* parameter creates foreign function wrappers with much more functionality than the features described above.

*paramflags* must be a tuple of the same length as *argtypes*.

Each item in this tuple contains further information about a parameter, it must be a tuple containing one, two, or three items.

The first item is an integer containing a combination of direction flags for the parameter:

- 1 Specifies an input parameter to the function.
- 2 Output parameter. The foreign function fills in a value.
- 4 Input parameter which defaults to the integer zero.

The optional second item is the parameter name as string. If this is specified, the foreign function can be called with named parameters.

The optional third item is the default value for this parameter.

This example demonstrates how to wrap the Windows `MessageBoxA` function so that it supports default parameters and named arguments. The C declaration from the windows header file is this:

```
WINUSERAPI int WINAPI
MessageBoxA(
    HWND hWnd,
    LPCSTR lpText,
    LPCSTR lpCaption,
    UINT uType);
```

Here is the wrapping with `ctypes`:

```
>>> from ctypes import c_int, WINFUNCTYPE, windll
>>> from ctypes.wintypes import HWND, LPCSTR, UINT
>>> prototype = WINFUNCTYPE(c_int, HWND, LPCSTR, LPCSTR, UINT)
>>> paramflags = (1, "hwnd", 0), (1, "text", "Hi"), (1, "caption", None), (1, "flags", 0)
>>> MessageBox = prototype(("MessageBoxA", windll.user32), paramflags)
>>>
```

The `MessageBox` foreign function can now be called in these ways:

```
>>> MessageBox()
>>> MessageBox(text="Spam, spam, spam")
>>> MessageBox(flags=2, text="foo bar")
>>>
```

A second example demonstrates output parameters. The win32 `GetWindowRect` function retrieves the dimensions of a specified window by copying them into `RECT` structure that the caller has to supply. Here is the C declaration:

```
WINUSERAPI BOOL WINAPI
GetWindowRect(
    HWND hWnd,
    LPRECT lpRect);
```

Here is the wrapping with `ctypes`:

```
>>> from ctypes import POINTER, WINFUNCTYPE, windll, WinError
>>> from ctypes.wintypes import BOOL, HWND, RECT
>>> prototype = WINFUNCTYPE(BOOL, HWND, POINTER(RECT))
>>> paramflags = (1, "hwnd"), (2, "lprect")
>>> GetWindowRect = prototype(("GetWindowRect", windll.user32), paramflags)
>>>
```

Functions with output parameters will automatically return the output parameter value if there is a single one, or a tuple containing the output parameter values when there are more than one, so the `GetWindowRect` function now returns a `RECT` instance, when called.

Output parameters can be combined with the `errcheck` protocol to do further output processing and error checking. The win32 `GetWindowRect` api function returns a `BOOL` to signal success or failure, so this function could do the error checking, and raises an exception when the api call failed:

```
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     return args
... 
```

```
>>> GetWindowRect.errcheck = errcheck
>>>
```

If the `errcheck` function returns the argument tuple it receives unchanged, `ctypes` continues the normal processing it does on the output parameters. If you want to return a tuple of window coordinates instead of a `RECT` instance, you can retrieve the fields in the function and return them instead, the normal processing will no longer take place:

```
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     rc = args[1]
...     return rc.left, rc.top, rc.bottom, rc.right
...
>>> GetWindowRect.errcheck = errcheck
>>>
```

### Utility functions

`ctypes.addressof(obj)`

Returns the address of the memory buffer as integer. *obj* must be an instance of a `ctypes` type.

`ctypes.alignment(obj_or_type)`

Returns the alignment requirements of a `ctypes` type. *obj\_or\_type* must be a `ctypes` type or instance.

`ctypes.byref(obj[, offset])`

Returns a light-weight pointer to *obj*, which must be an instance of a `ctypes` type. *offset* defaults to zero, and must be an integer that will be added to the internal pointer value.

`byref(obj, offset)` corresponds to this C code:

```
((char *)&obj) + offset)
```

The returned object can only be used as a foreign function call parameter. It behaves similar to `pointer(obj)`, but the construction is a lot faster. New in version 2.6: The *offset* optional argument was added.

`ctypes.cast(obj, type)`

This function is similar to the cast operator in C. It returns a new instance of *type* which points to the same memory block as *obj*. *type* must be a pointer type, and *obj* must be an object that can be interpreted as a pointer.

`ctypes.create_string_buffer(init_or_size[, size])`

This function creates a mutable character buffer. The returned object is a `ctypes` array of `c_char`.

*init\_or\_size* must be an integer which specifies the size of the array, or a string which will be used to initialize the array items.

If a string is specified as first argument, the buffer is made one item larger than the length of the string so that the last element in the array is a NUL termination character. An integer can be passed as second argument which allows to specify the size of the array if the length of the string should not be used.

If the first parameter is a unicode string, it is converted into an 8-bit string according to `ctypes` conversion rules.

`ctypes.create_unicode_buffer(init_or_size[, size])`

This function creates a mutable unicode character buffer. The returned object is a `ctypes` array of `c_wchar`.

*init\_or\_size* must be an integer which specifies the size of the array, or a unicode string which will be used to initialize the array items.

If a unicode string is specified as first argument, the buffer is made one item larger than the length of the string so that the last element in the array is a NUL termination character. An integer can be passed as second argument which allows to specify the size of the array if the length of the string should not be used.

If the first parameter is a 8-bit string, it is converted into an unicode string according to ctypes conversion rules.

`ctypes.DllCanUnloadNow()`

Windows only: This function is a hook which allows to implement in-process COM servers with ctypes. It is called from the `DllCanUnloadNow` function that the `_ctypes` extension dll exports.

`ctypes.DllGetClassObject()`

Windows only: This function is a hook which allows to implement in-process COM servers with ctypes. It is called from the `DllGetClassObject` function that the `_ctypes` extension dll exports.

`ctypes.util.find_library(name)`

Try to find a library and return a pathname. *name* is the library name without any prefix like `lib`, suffix like `.so`, `.dylib` or version number (this is the form used for the posix linker option `-l`). If no library can be found, returns `None`.

The exact functionality is system dependent. Changed in version 2.6: Windows only: `find_library("m")` or `find_library("c")` return the result of a call to `find_msvcr()`.

`ctypes.util.find_msvcr()`

Windows only: return the filename of the VC runtime library used by Python, and by the extension modules. If the name of the library cannot be determined, `None` is returned.

If you need to free memory, for example, allocated by an extension module with a call to the `free(void *)`, it is important that you use the function in the same library that allocated the memory. New in version 2.6.

`ctypes.FormatError([code])`

Windows only: Returns a textual description of the error code *code*. If no error code is specified, the last error code is used by calling the Windows api function `GetLastError`.

`ctypes.GetLastError()`

Windows only: Returns the last error code set by Windows in the calling thread. This function calls the Windows `GetLastError()` function directly, it does not return the ctypes-private copy of the error code.

`ctypes.get_errno()`

Returns the current value of the ctypes-private copy of the system `errno` variable in the calling thread. New in version 2.6.

`ctypes.get_last_error()`

Windows only: returns the current value of the ctypes-private copy of the system `LastError` variable in the calling thread. New in version 2.6.

`ctypes.memmove(dst, src, count)`

Same as the standard C `memmove` library function: copies *count* bytes from *src* to *dst*. *dst* and *src* must be integers or ctypes instances that can be converted to pointers.

`ctypes.memset(dst, c, count)`

Same as the standard C `memset` library function: fills the memory block at address *dst* with *count* bytes of value *c*. *dst* must be an integer specifying an address, or a ctypes instance.

`ctypes.POINTER(type)`

This factory function creates and returns a new ctypes pointer type. Pointer types are cached and reused internally, so calling this function repeatedly is cheap. *type* must be a ctypes type.

`ctypes.pointer(obj)`

This function creates a new pointer instance, pointing to *obj*. The returned object is of the type `POINTER(type(obj))`.

Note: If you just want to pass a pointer to an object to a foreign function call, you should use `byref(obj)` which is much faster.

`ctypes.resize(obj, size)`

This function resizes the internal memory buffer of *obj*, which must be an instance of a `ctypes` type. It is not possible to make the buffer smaller than the native size of the objects type, as given by `sizeof(type(obj))`, but it is possible to enlarge the buffer.

`ctypes.set_conversion_mode(encoding, errors)`

This function sets the rules that `ctypes` objects use when converting between 8-bit strings and unicode strings. *encoding* must be a string specifying an encoding, like `'utf-8'` or `'mbs'`, *errors* must be a string specifying the error handling on encoding/decoding errors. Examples of possible values are `"strict"`, `"replace"`, or `"ignore"`.

`set_conversion_mode()` returns a 2-tuple containing the previous conversion rules. On windows, the initial conversion rules are `('mbs', 'ignore')`, on other systems `('ascii', 'strict')`.

`ctypes.set_errno(value)`

Set the current value of the `ctypes`-private copy of the system `errno` variable in the calling thread to *value* and return the previous value. New in version 2.6.

`ctypes.set_last_error(value)`

Windows only: set the current value of the `ctypes`-private copy of the system `LastError` variable in the calling thread to *value* and return the previous value. New in version 2.6.

`ctypes.sizeof(obj_or_type)`

Returns the size in bytes of a `ctypes` type or instance memory buffer. Does the same as the C `sizeof()` function.

`ctypes.string_at(address[, size])`

This function returns the string starting at memory address *address*. If *size* is specified, it is used as *size*, otherwise the string is assumed to be zero-terminated.

`ctypes.WinError(code=None, descr=None)`

Windows only: this function is probably the worst-named thing in `ctypes`. It creates an instance of `WindowsError`. If *code* is not specified, `GetLastError` is called to determine the error code. If *descr* is not specified, `FormatError()` is called to get a textual description of the error.

`ctypes.wstring_at(address[, size])`

This function returns the wide character string starting at memory address *address* as unicode string. If *size* is specified, it is used as the number of characters of the string, otherwise the string is assumed to be zero-terminated.

## Data types

**class** `ctypes._CData`

This non-public class is the common base class of all `ctypes` data types. Among other things, all `ctypes` type instances contain a memory block that hold C compatible data; the address of the memory block is returned by the `addressof()` helper function. Another instance variable is exposed as `_objects`; this contains other Python objects that need to be kept alive in case the memory block contains pointers.

Common methods of `ctypes` data types, these are all class methods (to be exact, they are methods of the *meta-class*):

**from\_buffer** (*source*[, *offset*])

This method returns a `ctypes` instance that shares the buffer of the *source* object. The *source* object must support the writeable buffer interface. The optional *offset* parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a `ValueError` is raised. New in version 2.6.

**from\_buffer\_copy** (*source*[, *offset* ])

This method creates a `ctypes` instance, copying the buffer from the *source* object buffer which must be readable. The optional *offset* parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a `ValueError` is raised. New in version 2.6.

**from\_address** (*address*)

This method returns a `ctypes` type instance using the memory specified by *address* which must be an integer.

**from\_param** (*obj*)

This method adapts *obj* to a `ctypes` type. It is called with the actual object used in a foreign function call when the type is present in the foreign function's `argtypes` tuple; it must return an object that can be used as a function call parameter.

All `ctypes` data types have a default implementation of this classmethod that normally returns *obj* if that is an instance of the type. Some types accept other objects as well.

**in\_dll** (*library*, *name*)

This method returns a `ctypes` type instance exported by a shared library. *name* is the name of the symbol that exports the data, *library* is the loaded shared library.

Common instance variables of `ctypes` data types:

**`__b_base__`**

Sometimes `ctypes` data instances do not own the memory block they contain, instead they share part of the memory block of a base object. The `__b_base__` read-only member is the root `ctypes` object that owns the memory block.

**`__b_needsfree__`**

This read-only variable is true when the `ctypes` data instance has allocated the memory block itself, false otherwise.

**`__objects`**

This member is either `None` or a dictionary containing Python objects that need to be kept alive so that the memory block contents is kept valid. This object is only exposed for debugging; never modify the contents of this dictionary.

## Fundamental data types

**class** `ctypes._SimpleCData`

This non-public class is the base class of all fundamental `ctypes` data types. It is mentioned here because it contains the common attributes of the fundamental `ctypes` data types. `_SimpleCData` is a subclass of `_CData`, so it inherits their methods and attributes. Changed in version 2.6: `ctypes` data types that are not and do not contain pointers can now be pickled. Instances have a single attribute:

**value**

This attribute contains the actual value of the instance. For integer and pointer types, it is an integer, for character types, it is a single character string, for character pointer types it is a Python string or unicode string.

When the `value` attribute is retrieved from a `ctypes` instance, usually a new object is returned each time. `ctypes` does *not* implement original object return, always a new object is constructed. The same is true for all other `ctypes` object instances.

Fundamental data types, when returned as foreign function call results, or, for example, by retrieving structure field members or array items, are transparently converted to native Python types. In other words, if a foreign function has a `restype` of `c_char_p`, you will always receive a Python string, *not* a `c_char_p` instance.

Subclasses of fundamental data types do *not* inherit this behavior. So, if a foreign functions `restype` is a subclass of `c_void_p`, you will receive an instance of this subclass from the function call. Of course, you can get the value of the pointer by accessing the `value` attribute.

These are the fundamental ctypes data types:

**class** `ctypes.c_byte`

Represents the C `signed char` datatype, and interprets the value as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.

**class** `ctypes.c_char`

Represents the C `char` datatype, and interprets the value as a single character. The constructor accepts an optional string initializer, the length of the string must be exactly one character.

**class** `ctypes.c_char_p`

Represents the C `char *` datatype when it points to a zero-terminated string. For a general character pointer that may also point to binary data, `POINTER(c_char)` must be used. The constructor accepts an integer address, or a string.

**class** `ctypes.c_double`

Represents the C `double` datatype. The constructor accepts an optional float initializer.

**class** `ctypes.c_longdouble`

Represents the C `long double` datatype. The constructor accepts an optional float initializer. On platforms where `sizeof(long double) == sizeof(double)` it is an alias to `c_double`. New in version 2.6.

**class** `ctypes.c_float`

Represents the C `float` datatype. The constructor accepts an optional float initializer.

**class** `ctypes.c_int`

Represents the C `signed int` datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where `sizeof(int) == sizeof(long)` it is an alias to `c_long`.

**class** `ctypes.c_int8`

Represents the C 8-bit `signed int` datatype. Usually an alias for `c_byte`.

**class** `ctypes.c_int16`

Represents the C 16-bit `signed int` datatype. Usually an alias for `c_short`.

**class** `ctypes.c_int32`

Represents the C 32-bit `signed int` datatype. Usually an alias for `c_int`.

**class** `ctypes.c_int64`

Represents the C 64-bit `signed int` datatype. Usually an alias for `c_longlong`.

**class** `ctypes.c_long`

Represents the C `signed long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

**class** `ctypes.c_longlong`

Represents the C `signed long long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

**class** `ctypes.c_short`

Represents the C `signed short` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

**class** `ctypes.c_size_t`

Represents the C `size_t` datatype.

**class** `ctypes.c_ssize_t`

Represents the C `ssize_t` datatype. New in version 2.7.

- class** `ctypes.c_ubyte`  
Represents the C `unsigned char` datatype, it interprets the value as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.
- class** `ctypes.c_uint`  
Represents the C `unsigned int` datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where `sizeof(int) == sizeof(long)` it is an alias for `c_ulong`.
- class** `ctypes.c_uint8`  
Represents the C 8-bit `unsigned int` datatype. Usually an alias for `c_ubyte`.
- class** `ctypes.c_uint16`  
Represents the C 16-bit `unsigned int` datatype. Usually an alias for `c_ushort`.
- class** `ctypes.c_uint32`  
Represents the C 32-bit `unsigned int` datatype. Usually an alias for `c_uint`.
- class** `ctypes.c_uint64`  
Represents the C 64-bit `unsigned int` datatype. Usually an alias for `c_ulonglong`.
- class** `ctypes.c_ulong`  
Represents the C `unsigned long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.
- class** `ctypes.c_ulonglong`  
Represents the C `unsigned long long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.
- class** `ctypes.c_ushort`  
Represents the C `unsigned short` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.
- class** `ctypes.c_void_p`  
Represents the C `void *` type. The value is represented as integer. The constructor accepts an optional integer initializer.
- class** `ctypes.c_wchar`  
Represents the C `wchar_t` datatype, and interprets the value as a single character unicode string. The constructor accepts an optional string initializer, the length of the string must be exactly one character.
- class** `ctypes.c_wchar_p`  
Represents the C `wchar_t *` datatype, which must be a pointer to a zero-terminated wide character string. The constructor accepts an integer address, or a string.
- class** `ctypes.c_bool`  
Represent the C `bool` datatype (more accurately, `_Bool` from C99). Its value can be True or False, and the constructor accepts any object that has a truth value. New in version 2.6.
- class** `ctypes.HRESULT`  
Windows only: Represents a HRESULT value, which contains success or error information for a function or method call.
- class** `ctypes.py_object`  
Represents the C `PyObject *` datatype. Calling this without an argument creates a NULL `PyObject *` pointer.

The `ctypes.wintypes` module provides quite some other Windows specific data types, for example `HWND`, `WPARAM`, or `DWORD`. Some useful structures like `MSG` or `RECT` are also defined.

## Structured data types

**class** `ctypes.Union` (\*args, \*\*kw)  
Abstract base class for unions in native byte order.

**class** `ctypes.BigEndianStructure` (\*args, \*\*kw)  
Abstract base class for structures in *big endian* byte order.

**class** `ctypes.LittleEndianStructure` (\*args, \*\*kw)  
Abstract base class for structures in *little endian* byte order.

Structures with non-native byte order cannot contain pointer type fields, or any other data types containing pointer type fields.

**class** `ctypes.Structure` (\*args, \*\*kw)  
Abstract base class for structures in *native* byte order.

Concrete structure and union types must be created by subclassing one of these types, and at least define a `__fields__` class variable. `ctypes` will create *descriptors* which allow reading and writing the fields by direct attribute accesses. These are the

### `__fields__`

A sequence defining the structure fields. The items must be 2-tuples or 3-tuples. The first item is the name of the field, the second item specifies the type of the field; it can be any `ctypes` data type.

For integer type fields like `c_int`, a third optional item can be given. It must be a small positive integer defining the bit width of the field.

Field names must be unique within one structure or union. This is not checked, only one field can be accessed when names are repeated.

It is possible to define the `__fields__` class variable *after* the class statement that defines the Structure subclass, this allows to create data types that directly or indirectly reference themselves:

```
class List(Structure):  
    pass  
List.__fields__ = [("pnext", POINTER(List)),  
                  ...  
                  ]
```

The `__fields__` class variable must, however, be defined before the type is first used (an instance is created, `sizeof()` is called on it, and so on). Later assignments to the `__fields__` class variable will raise an `AttributeError`.

Structure and union subclass constructors accept both positional and named arguments. Positional arguments are used to initialize the fields in the same order as they appear in the `__fields__` definition, named arguments are used to initialize the fields with the corresponding name.

It is possible to defined sub-subclasses of structure types, they inherit the fields of the base class plus the `__fields__` defined in the sub-subclass, if any.

### `__pack__`

An optional small integer that allows to override the alignment of structure fields in the instance. `__pack__` must already be defined when `__fields__` is assigned, otherwise it will have no effect.

### `__anonymous__`

An optional sequence that lists the names of unnamed (anonymous) fields. `__anonymous__` must be already defined when `__fields__` is assigned, otherwise it will have no effect.

The fields listed in this variable must be structure or union type fields. `ctypes` will create descriptors in the structure type that allows to access the nested fields directly, without the need to create the structure or union field.

Here is an example type (Windows):

```
class _U(Union):
    _fields_ = [ ("lptdesc", POINTER(TYPEDESC)),
                ("lpadesc", POINTER(ARRAYDESC)),
                ("hreftype", HREFTYPE) ]

class TYPEDESC(Structure):
    _anonymous_ = ("u",)
    _fields_ = [ ("u", _U),
                ("vt", VARTYPE) ]
```

The `TYPEDESC` structure describes a COM data type, the `vt` field specifies which one of the union fields is valid. Since the `u` field is defined as anonymous field, it is now possible to access the members directly off the `TYPEDESC` instance. `td.lptdesc` and `td.u.lptdesc` are equivalent, but the former is faster since it does not need to create a temporary union instance:

```
td = TYPEDESC()
td.vt = VT_PTR
td.lptdesc = POINTER(some_type)
td.u.lptdesc = POINTER(some_type)
```

It is possible to defined sub-subclasses of structures, they inherit the fields of the base class. If the subclass definition has a separate `_fields_` variable, the fields specified in this are appended to the fields of the base class.

Structure and union constructors accept both positional and keyword arguments. Positional arguments are used to initialize member fields in the same order as they appear in `_fields_`. Keyword arguments in the constructor are interpreted as attribute assignments, so they will initialize `_fields_` with the same name, or create new attributes for names not present in `_fields_`.

## Arrays and pointers

Not yet written - please see the sections *Pointers* and section *Arrays* in the tutorial.



# OPTIONAL OPERATING SYSTEM SERVICES

The modules described in this chapter provide interfaces to operating system features that are available on selected operating systems only. The interfaces are generally modeled after the Unix or C interfaces but they are available on some other systems as well (e.g. Windows or NT). Here's an overview:

## 16.1 `select` — Waiting for I/O completion

This module provides access to the `select()` and `poll()` functions available in most operating systems, `epoll()` available on Linux 2.5+ and `kqueue()` available on most BSD. Note that on Windows, it only works for sockets; on other operating systems, it also works for other file types (in particular, on Unix, it works on pipes). It cannot be used on regular files to determine whether a file has grown since it was last read.

The module defines the following:

### exception `select.error`

The exception raised when an error occurs. The accompanying value is a pair containing the numeric error code from `errno` and the corresponding string, as would be printed by the C function `perror()`.

### `select.epoll([sizehint=-1])`

(Only supported on Linux 2.5.44 and newer.) Returns an edge polling object, which can be used as Edge or Level Triggered interface for I/O events; see section *Edge and Level Trigger Polling (epoll) Objects* below for the methods supported by epolling objects. New in version 2.6.

### `select.poll()`

(Not supported by all operating systems.) Returns a polling object, which supports registering and unregistering file descriptors, and then polling them for I/O events; see section *Polling Objects* below for the methods supported by polling objects.

### `select.kqueue()`

(Only supported on BSD.) Returns a kernel queue object; see section *Kqueue Objects* below for the methods supported by kqueue objects. New in version 2.6.

### `select.kevent(ident, filter=KQ_FILTER_READ, flags=KQ_EV_ADD, fflags=0, data=0, udata=0)`

(Only supported on BSD.) Returns a kernel event object; see section *Kevent Objects* below for the methods supported by kevent objects. New in version 2.6.

### `select.select(rlist, wlist, xlist[, timeout])`

This is a straightforward interface to the Unix `select()` system call. The first three arguments are sequences of 'waitable objects': either integers representing file descriptors or objects with a parameterless method named `fileno()` returning such an integer:

- rlist*: wait until ready for reading
- wlist*: wait until ready for writing
- xlist*: wait for an “exceptional condition” (see the manual page for what your system considers such a condition)

Empty sequences are allowed, but acceptance of three empty sequences is platform-dependent. (It is known to work on Unix but not on Windows.) The optional *timeout* argument specifies a time-out as a floating point number in seconds. When the *timeout* argument is omitted the function blocks until at least one file descriptor is ready. A time-out value of zero specifies a poll and never blocks.

The return value is a triple of lists of objects that are ready: subsets of the first three arguments. When the time-out is reached without a file descriptor becoming ready, three empty lists are returned.

Among the acceptable object types in the sequences are Python file objects (e.g. `sys.stdin`, or objects returned by `open()` or `os.popen()`), socket objects returned by `socket.socket()`. You may also define a *wrapper* class yourself, as long as it has an appropriate `fileno()` method (that really returns a file descriptor, not just a random integer).

---

**Note:** File objects on Windows are not acceptable, but sockets are. On Windows, the underlying `select()` function is provided by the WinSock library, and does not handle file descriptors that don't originate from WinSock.

---

`select.PIPE_BUF`

Files reported as ready for writing by `select()`, `poll()` or similar interfaces in this module are guaranteed to not block on a write of up to `PIPE_BUF` bytes. This value is guaranteed by POSIX to be at least 512. Availability: Unix. New in version 2.7.

### 16.1.1 Edge and Level Trigger Polling (epoll) Objects

<http://linux.die.net/man/4/epoll>

*eventmask*

Constant	Meaning
EPOLLIN	Available for read
EPOLLOUT	Available for write
EPOLLPRI	Urgent data for read
EPOLLERR	Error condition happened on the assoc. fd
EPOLLHUP	Hang up happened on the assoc. fd
EPOLLET	Set Edge Trigger behavior, the default is Level Trigger behavior
EPOLLONESHOT	Set one-shot behavior. After one event is pulled out, the fd is internally disabled
EPOLLRDNORM	Equivalent to EPOLLIN
EPOLLRDBAND	Priority data band can be read.
EPOLLWRNORM	Equivalent to EPOLLOUT
EPOLLWRBAND	Priority data may be written.
EPOLLMSG	Ignored.

- `epoll.close()`  
Close the control file descriptor of the epoll object.
- `epoll.fileno()`  
Return the file descriptor number of the control fd.
- `epoll.fromfd(fd)`  
Create an epoll object from a given file descriptor.

`epoll.register` (*fd* [, *eventmask* ])  
Register a *fd* descriptor with the `epoll` object.

---

**Note:** Registering a file descriptor that's already registered raises an `IOError` – contrary to *Polling Objects*'s `register`.

---

`epoll.modify` (*fd*, *eventmask*)  
Modify a registered file descriptor.

`epoll.unregister` (*fd*)  
Remove a registered file descriptor from the `epoll` object.

`epoll.poll` ([*timeout=-1* [, *maxevents=-1* ]])  
Wait for events. *timeout* in seconds (float)

## 16.1.2 Polling Objects

The `poll()` system call, supported on most Unix systems, provides better scalability for network servers that service many, many clients at the same time. `poll()` scales better because the system call only requires listing the file descriptors of interest, while `select()` builds a bitmap, turns on bits for the *fds* of interest, and then afterward the whole bitmap has to be linearly scanned again. `select()` is  $O(\text{highest file descriptor})$ , while `poll()` is  $O(\text{number of file descriptors})$ .

`poll.register` (*fd* [, *eventmask* ])  
Register a file descriptor with the polling object. Future calls to the `poll()` method will then check whether the file descriptor has any pending I/O events. *fd* can be either an integer, or an object with a `fileno()` method that returns an integer. File objects implement `fileno()`, so they can also be used as the argument.

*eventmask* is an optional bitmask describing the type of events you want to check for, and can be a combination of the constants `POLLIN`, `POLLPRI`, and `POLLOUT`, described in the table below. If not specified, the default value used will check for all 3 types of events.

Constant	Meaning
<code>POLLIN</code>	There is data to read
<code>POLLPRI</code>	There is urgent data to read
<code>POLLOUT</code>	Ready for output: writing will not block
<code>POLLERR</code>	Error condition of some sort
<code>POLLHUP</code>	Hung up
<code>POLLNVAL</code>	Invalid request: descriptor not open

Registering a file descriptor that's already registered is not an error, and has the same effect as registering the descriptor exactly once.

`poll.modify` (*fd*, *eventmask*)  
Modifies an already registered *fd*. This has the same effect as `register(fd, eventmask)`. Attempting to modify a file descriptor that was never registered causes an `IOError` exception with `errno.ENOENT` to be raised. New in version 2.6.

`poll.unregister` (*fd*)  
Remove a file descriptor being tracked by a polling object. Just like the `register()` method, *fd* can be an integer or an object with a `fileno()` method that returns an integer.

Attempting to remove a file descriptor that was never registered causes a `KeyError` exception to be raised.

`poll.poll` ([*timeout* ])  
Polls the set of registered file descriptors, and returns a possibly-empty list containing (*fd*, *event*) 2-tuples for the descriptors that have events or errors to report. *fd* is the file descriptor, and *event* is a bitmask with bits set

for the reported events for that descriptor — `POLLIN` for waiting input, `POLLOUT` to indicate that the descriptor can be written to, and so forth. An empty list indicates that the call timed out and no file descriptors had any events to report. If *timeout* is given, it specifies the length of time in milliseconds which the system will wait for events before returning. If *timeout* is omitted, negative, or `None`, the call will block until there is an event for this poll object.

### 16.1.3 Kqueue Objects

`kqueue.close()`

Close the control file descriptor of the kqueue object.

`kqueue.fileno()`

Return the file descriptor number of the control fd.

`kqueue.fromfd(fd)`

Create a kqueue object from a given file descriptor.

`kqueue.control(changelist, max_events[, timeout=None])` → eventlist

Low level interface to kevent

- *changelist* must be an iterable of kevent object or None
- *max\_events* must be 0 or a positive integer
- *timeout* in seconds (floats possible)

### 16.1.4 Kevent Objects

<http://www.freebsd.org/cgi/man.cgi?query=kqueue&sektion=2>

`kevent.ident`

Value used to identify the event. The interpretation depends on the filter but it's usually the file descriptor. In the constructor *ident* can either be an int or an object with a `fileno()` function. `kevent` stores the integer internally.

`kevent.filter`

Name of the kernel filter.

Constant	Meaning
<code>KQ_FILTER_READ</code>	Takes a descriptor and returns whenever there is data available to read
<code>KQ_FILTER_WRITE</code>	Takes a descriptor and returns whenever there is data available to write
<code>KQ_FILTER_AIO</code>	AIO requests
<code>KQ_FILTER_VNODE</code>	Returns when one or more of the requested events watched in <i>fflag</i> occurs
<code>KQ_FILTER_PROC</code>	Watch for events on a process id
<code>KQ_FILTER_NETDEV</code>	Watch for events on a network device [not available on Mac OS X]
<code>KQ_FILTER_SIGNAL</code>	Returns whenever the watched signal is delivered to the process
<code>KQ_FILTER_TIMER</code>	Establishes an arbitrary timer

`kevent.flags`

Filter action.

Constant	Meaning
KQ_EV_ADD	Adds or modifies an event
KQ_EV_DELETE	Removes an event from the queue
KQ_EV_ENABLE	Permits <code>control()</code> to return the event
KQ_EV_DISABLE	Disable event
KQ_EV_ONESHOT	Removes event after first occurrence
KQ_EV_CLEAR	Reset the state after an event is retrieved
KQ_EV_SYSFLAGS	internal event
KQ_EV_FLAG1	internal event
KQ_EV_EOF	Filter specific EOF condition
KQ_EV_ERROR	See return values

**kevent.flags**

Filter specific flags.

KQ\_FILTER\_READ and KQ\_FILTER\_WRITE filter flags:

Constant	Meaning
KQ_NOTE_LOWAT	low water mark of a socket buffer

KQ\_FILTER\_VNODE filter flags:

Constant	Meaning
KQ_NOTE_DELETE	<i>unlink()</i> was called
KQ_NOTE_WRITE	a write occurred
KQ_NOTE_EXTEND	the file was extended
KQ_NOTE_ATTRIB	an attribute was changed
KQ_NOTE_LINK	the link count has changed
KQ_NOTE_RENAME	the file was renamed
KQ_NOTE_REVOKE	access to the file was revoked

KQ\_FILTER\_PROC filter flags:

Constant	Meaning
KQ_NOTE_EXIT	the process has exited
KQ_NOTE_FORK	the process has called <i>fork()</i>
KQ_NOTE_EXEC	the process has executed a new process
KQ_NOTE_PCTRLMASK	internal filter flag
KQ_NOTE_PDATAMASK	internal filter flag
KQ_NOTE_TRACK	follow a process across <i>fork()</i>
KQ_NOTE_CHILD	returned on the child process for <i>NOTE_TRACK</i>
KQ_NOTE_TRACKERR	unable to attach to a child

KQ\_FILTER\_NETDEV filter flags (not available on Mac OS X):

Constant	Meaning
KQ_NOTE_LINKUP	link is up
KQ_NOTE_LINKDOWN	link is down
KQ_NOTE_LINKINV	link state is invalid

**kevent.data**

Filter specific data.

**kevent.udata**

User defined value.

## 16.2 threading — Higher-level threading interface

**Source code:** `Lib/threading.py`

---

This module constructs higher-level threading interfaces on top of the lower level `thread` module. See also the `mutex` and `Queue` modules.

The `dummy_threading` module is provided for situations where `threading` cannot be used because `thread` is missing.

---

**Note:** Starting with Python 2.6, this module provides **PEP 8** compliant aliases and properties to replace the camelCase names that were inspired by Java's threading API. This updated API is compatible with that of the `multiprocessing` module. However, no schedule has been set for the deprecation of the camelCase names and they remain fully supported in both Python 2.x and 3.x.

---

**Note:** Starting with Python 2.5, several Thread methods raise `RuntimeError` instead of `AssertionError` if called erroneously.

---

**CPython implementation detail:** Due to the *Global Interpreter Lock*, in CPython only one thread can execute Python code at once (even though certain performance-oriented libraries might overcome this limitation). If you want your application to make better use of the computational resources of multi-core machines, you are advised to use `multiprocessing`. However, threading is still an appropriate model if you want to run multiple I/O-bound tasks simultaneously.

This module defines the following functions and objects:

`threading.active_count()`

`threading.activeCount()`

Return the number of `Thread` objects currently alive. The returned count is equal to the length of the list returned by `enumerate()`.

`threading.Condition()`

A factory function that returns a new condition variable object. A condition variable allows one or more threads to wait until they are notified by another thread.

See *Condition Objects*.

`threading.current_thread()`

`threading.currentThread()`

Return the current `Thread` object, corresponding to the caller's thread of control. If the caller's thread of control was not created through the `threading` module, a dummy thread object with limited functionality is returned.

`threading.enumerate()`

Return a list of all `Thread` objects currently alive. The list includes daemon threads, dummy thread objects created by `current_thread()`, and the main thread. It excludes terminated threads and threads that have not yet been started.

`threading.Event()`

A factory function that returns a new event object. An event manages a flag that can be set to true with the `set()` method and reset to false with the `clear()` method. The `wait()` method blocks until the flag is true.

See *Event Objects*.

**class** `threading.local`

A class that represents thread-local data. Thread-local data are data whose values are thread specific. To manage thread-local data, just create an instance of `local` (or a subclass) and store attributes on it:

```
mydata = threading.local()
mydata.x = 1
```

The instance's values will be different for separate threads.

For more details and extensive examples, see the documentation string of the `_threading_local` module. New in version 2.4.

`threading.Lock()`

A factory function that returns a new primitive lock object. Once a thread has acquired it, subsequent attempts to acquire it block, until it is released; any thread may release it.

See *Lock Objects*.

`threading.RLock()`

A factory function that returns a new reentrant lock object. A reentrant lock must be released by the thread that acquired it. Once a thread has acquired a reentrant lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

See *RLock Objects*.

`threading.Semaphore([value])`

A factory function that returns a new semaphore object. A semaphore manages a counter representing the number of `release()` calls minus the number of `acquire()` calls, plus an initial value. The `acquire()` method blocks if necessary until it can return without making the counter negative. If not given, *value* defaults to 1.

See *Semaphore Objects*.

`threading.BoundedSemaphore([value])`

A factory function that returns a new bounded semaphore object. A bounded semaphore checks to make sure its current value doesn't exceed its initial value. If it does, `ValueError` is raised. In most situations semaphores are used to guard resources with limited capacity. If the semaphore is released too many times it's a sign of a bug. If not given, *value* defaults to 1.

**class** `threading.Thread`

A class that represents a thread of control. This class can be safely subclassed in a limited fashion.

See *Thread Objects*.

**class** `threading.Timer`

A thread that executes a function after a specified interval has passed.

See *Timer Objects*.

`threading.settrace(func)`

Set a trace function for all threads started from the `threading` module. The *func* will be passed to `sys.settrace()` for each thread, before its `run()` method is called. New in version 2.3.

`threading.setprofile(func)`

Set a profile function for all threads started from the `threading` module. The *func* will be passed to `sys.setprofile()` for each thread, before its `run()` method is called. New in version 2.3.

`threading.stack_size([size])`

Return the thread stack size used when creating new threads. The optional *size* argument specifies the stack size to be used for subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32kB). If changing the thread stack size is unsupported, a `ThreadError`

is raised. If the specified stack size is invalid, a `ValueError` is raised and the stack size is unmodified. 32kB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32kB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4kB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads. New in version 2.5.

Detailed interfaces for the objects are documented below.

The design of this module is loosely based on Java's threading model. However, where Java makes locks and condition variables basic behavior of every object, they are separate objects in Python. Python's `Thread` class supports a subset of the behavior of Java's `Thread` class; currently, there are no priorities, no thread groups, and threads cannot be destroyed, stopped, suspended, resumed, or interrupted. The static methods of Java's `Thread` class, when implemented, are mapped to module-level functions.

All of the methods described below are executed atomically.

### 16.2.1 Thread Objects

This class represents an activity that is run in a separate thread of control. There are two ways to specify the activity: by passing a callable object to the constructor, or by overriding the `run()` method in a subclass. No other methods (except for the constructor) should be overridden in a subclass. In other words, *only* override the `__init__()` and `run()` methods of this class.

Once a thread object is created, its activity must be started by calling the thread's `start()` method. This invokes the `run()` method in a separate thread of control.

Once the thread's activity is started, the thread is considered 'alive'. It stops being alive when its `run()` method terminates – either normally, or by raising an unhandled exception. The `is_alive()` method tests whether the thread is alive.

Other threads can call a thread's `join()` method. This blocks the calling thread until the thread whose `join()` method is called is terminated.

A thread has a name. The name can be passed to the constructor, and read or changed through the `name` attribute.

A thread can be flagged as a "daemon thread". The significance of this flag is that the entire Python program exits when only daemon threads are left. The initial value is inherited from the creating thread. The flag can be set through the `daemon` property.

There is a "main thread" object; this corresponds to the initial thread of control in the Python program. It is not a daemon thread.

There is the possibility that "dummy thread objects" are created. These are thread objects corresponding to "alien threads", which are threads of control started outside the threading module, such as directly from C code. Dummy thread objects have limited functionality; they are always considered alive and daemonic, and cannot be `join()`ed. They are never deleted, since it is impossible to detect the termination of alien threads.

**class** `threading.Thread`(*group=None, target=None, name=None, args=(), kwargs={}*)

This constructor should always be called with keyword arguments. Arguments are:

*group* should be `None`; reserved for future extension when a `ThreadGroup` class is implemented.

*target* is the callable object to be invoked by the `run()` method. Defaults to `None`, meaning nothing is called.

*name* is the thread name. By default, a unique name is constructed of the form "Thread-*N*" where *N* is a small decimal number.

*args* is the argument tuple for the target invocation. Defaults to `()`.

*kwargs* is a dictionary of keyword arguments for the target invocation. Defaults to `{}`.

If the subclass overrides the constructor, it must make sure to invoke the base class constructor (`Thread.__init__()`) before doing anything else to the thread.

#### **start()**

Start the thread's activity.

It must be called at most once per thread object. It arranges for the object's `run()` method to be invoked in a separate thread of control.

This method will raise a `RuntimeError` if called more than once on the same thread object.

#### **run()**

Method representing the thread's activity.

You may override this method in a subclass. The standard `run()` method invokes the callable object passed to the object's constructor as the *target* argument, if any, with sequential and keyword arguments taken from the *args* and *kwargs* arguments, respectively.

#### **join([timeout])**

Wait until the thread terminates. This blocks the calling thread until the thread whose `join()` method is called terminates – either normally or through an unhandled exception – or until the optional timeout occurs.

When the *timeout* argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof). As `join()` always returns `None`, you must call `isAlive()` after `join()` to decide whether a timeout happened – if the thread is still alive, the `join()` call timed out.

When the *timeout* argument is not present or `None`, the operation will block until the thread terminates.

A thread can be `join()`ed many times.

`join()` raises a `RuntimeError` if an attempt is made to join the current thread as that would cause a deadlock. It is also an error to `join()` a thread before it has been started and attempts to do so raises the same exception.

#### **getName()**

#### **setName()**

Old API for `name`.

#### **name**

A string used for identification purposes only. It has no semantics. Multiple threads may be given the same name. The initial name is set by the constructor.

#### **ident**

The 'thread identifier' of this thread or `None` if the thread has not been started. This is a nonzero integer. See the `thread.get_ident()` function. Thread identifiers may be recycled when a thread exits and another thread is created. The identifier is available even after the thread has exited. New in version 2.6.

#### **is\_alive()**

#### **isAlive()**

Return whether the thread is alive.

This method returns `True` just before the `run()` method starts until just after the `run()` method terminates. The module function `enumerate()` returns a list of all alive threads.

#### **isDaemon()**

#### **setDaemon()**

Old API for `daemon`.

### **daemon**

A boolean value indicating whether this thread is a daemon thread (True) or not (False). This must be set before `start()` is called, otherwise `RuntimeError` is raised. Its initial value is inherited from the creating thread; the main thread is not a daemon thread and therefore all threads created in the main thread default to `daemon = False`.

The entire Python program exits when no alive non-daemon threads are left.

## 16.2.2 Lock Objects

A primitive lock is a synchronization primitive that is not owned by a particular thread when locked. In Python, it is currently the lowest level synchronization primitive available, implemented directly by the `thread` extension module.

A primitive lock is in one of two states, “locked” or “unlocked”. It is created in the unlocked state. It has two basic methods, `acquire()` and `release()`. When the state is unlocked, `acquire()` changes the state to locked and returns immediately. When the state is locked, `acquire()` blocks until a call to `release()` in another thread changes it to unlocked, then the `acquire()` call resets it to locked and returns. The `release()` method should only be called in the locked state; it changes the state to unlocked and returns immediately. If an attempt is made to release an unlocked lock, a `RuntimeError` will be raised.

When more than one thread is blocked in `acquire()` waiting for the state to turn to unlocked, only one thread proceeds when a `release()` call resets the state to unlocked; which one of the waiting threads proceeds is not defined, and may vary across implementations.

All methods are executed atomically.

`Lock.acquire([blocking])`

Acquire a lock, blocking or non-blocking.

When invoked with the `blocking` argument set to `True` (the default), block until the lock is unlocked, then set it to locked and return `True`.

When invoked with the `blocking` argument set to `False`, do not block. If a call with `blocking` set to `True` would block, return `False` immediately; otherwise, set the lock to locked and return `True`.

`Lock.release()`

Release a lock.

When the lock is locked, reset it to unlocked, and return. If any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a `ThreadError` is raised.

There is no return value.

## 16.2.3 RLock Objects

A reentrant lock is a synchronization primitive that may be acquired multiple times by the same thread. Internally, it uses the concepts of “owning thread” and “recursion level” in addition to the locked/unlocked state used by primitive locks. In the locked state, some thread owns the lock; in the unlocked state, no thread owns it.

To lock the lock, a thread calls its `acquire()` method; this returns once the thread owns the lock. To unlock the lock, a thread calls its `release()` method. `acquire()/release()` call pairs may be nested; only the final `release()` (the `release()` of the outermost pair) resets the lock to unlocked and allows another thread blocked in `acquire()` to proceed.

`RLock.acquire([blocking=1])`

Acquire a lock, blocking or non-blocking.

When invoked without arguments: if this thread already owns the lock, increment the recursion level by one, and return immediately. Otherwise, if another thread owns the lock, block until the lock is unlocked. Once the lock is unlocked (not owned by any thread), then grab ownership, set the recursion level to one, and return. If more than one thread is blocked waiting until the lock is unlocked, only one at a time will be able to grab ownership of the lock. There is no return value in this case.

When invoked with the *blocking* argument set to true, do the same thing as when called without arguments, and return true.

When invoked with the *blocking* argument set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

`RLock.release()`

Release a lock, decrementing the recursion level. If after the decrement it is zero, reset the lock to unlocked (not owned by any thread), and if any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed. If after the decrement the recursion level is still nonzero, the lock remains locked and owned by the calling thread.

Only call this method when the calling thread owns the lock. A `RuntimeError` is raised if this method is called when the lock is unlocked.

There is no return value.

## 16.2.4 Condition Objects

A condition variable is always associated with some kind of lock; this can be passed in or one will be created by default. (Passing one in is useful when several condition variables must share the same lock.)

A condition variable has `acquire()` and `release()` methods that call the corresponding methods of the associated lock. It also has a `wait()` method, and `notify()` and `notifyAll()` methods. These three must only be called when the calling thread has acquired the lock, otherwise a `RuntimeError` is raised.

The `wait()` method releases the lock, and then blocks until it is awakened by a `notify()` or `notifyAll()` call for the same condition variable in another thread. Once awakened, it re-acquires the lock and returns. It is also possible to specify a timeout.

The `notify()` method wakes up one of the threads waiting for the condition variable, if any are waiting. The `notifyAll()` method wakes up all threads waiting for the condition variable.

**Note:** the `notify()` and `notifyAll()` methods don't release the lock; this means that the thread or threads awakened will not return from their `wait()` call immediately, but only when the thread that called `notify()` or `notifyAll()` finally relinquishes ownership of the lock.

**Tip:** the typical programming style using condition variables uses the lock to synchronize access to some shared state; threads that are interested in a particular change of state call `wait()` repeatedly until they see the desired state, while threads that modify the state call `notify()` or `notifyAll()` when they change the state in such a way that it could possibly be a desired state for one of the waiters. For example, the following code is a generic producer-consumer situation with unlimited buffer capacity:

```
# Consume one item
cv.acquire()
while not an_item_is_available():
    cv.wait()
get_an_available_item()
cv.release()

# Produce one item
cv.acquire()
make_an_item_available()
```

```
cv.notify()  
cv.release()
```

To choose between `notify()` and `notifyAll()`, consider whether one state change can be interesting for only one or several waiting threads. E.g. in a typical producer-consumer situation, adding one item to the buffer only needs to wake up one consumer thread.

**class** `threading.Condition` (`[lock]`)

If the `lock` argument is given and not `None`, it must be a `Lock` or `RLock` object, and it is used as the underlying lock. Otherwise, a new `RLock` object is created and used as the underlying lock.

**acquire** (`*args`)

Acquire the underlying lock. This method calls the corresponding method on the underlying lock; the return value is whatever that method returns.

**release** ()

Release the underlying lock. This method calls the corresponding method on the underlying lock; there is no return value.

**wait** (`[timeout]`)

Wait until notified or until a timeout occurs. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method releases the underlying lock, and then blocks until it is awakened by a `notify()` or `notifyAll()` call for the same condition variable in another thread, or until the optional timeout occurs. Once awakened or timed out, it re-acquires the lock and returns.

When the `timeout` argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

When the underlying lock is an `RLock`, it is not released using its `release()` method, since this may not actually unlock the lock when it was acquired multiple times recursively. Instead, an internal interface of the `RLock` class is used, which really unlocks it even when it has been recursively acquired several times. Another internal interface is then used to restore the recursion level when the lock is reacquired.

**notify** (`n=1`)

By default, wake up one thread waiting on this condition, if any. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method wakes up at most `n` of the threads waiting for the condition variable; it is a no-op if no threads are waiting.

The current implementation wakes up exactly `n` threads, if at least `n` threads are waiting. However, it's not safe to rely on this behavior. A future, optimized implementation may occasionally wake up more than `n` threads.

Note: an awakened thread does not actually return from its `wait()` call until it can reacquire the lock. Since `notify()` does not release the lock, its caller should.

**notify\_all** ()

**notifyAll** ()

Wake up all threads waiting on this condition. This method acts like `notify()`, but wakes up all waiting threads instead of one. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.

## 16.2.5 Semaphore Objects

This is one of the oldest synchronization primitives in the history of computer science, invented by the early Dutch computer scientist Edsger W. Dijkstra (he used `P()` and `V()` instead of `acquire()` and `release()`).

A semaphore manages an internal counter which is decremented by each `acquire()` call and incremented by each `release()` call. The counter can never go below zero; when `acquire()` finds that it is zero, it blocks, waiting until some other thread calls `release()`.

**class** `threading.Semaphore` (`[value]`)

The optional argument gives the initial *value* for the internal counter; it defaults to 1. If the *value* given is less than 0, `ValueError` is raised.

**acquire** (`[blocking]`)

Acquire a semaphore.

When invoked without arguments: if the internal counter is larger than zero on entry, decrement it by one and return immediately. If it is zero on entry, block, waiting until some other thread has called `release()` to make it larger than zero. This is done with proper interlocking so that if multiple `acquire()` calls are blocked, `release()` will wake exactly one of them up. The implementation may pick one at random, so the order in which blocked threads are awakened should not be relied on. There is no return value in this case.

When invoked with *blocking* set to true, do the same thing as when called without arguments, and return true.

When invoked with *blocking* set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

**release** ()

Release a semaphore, incrementing the internal counter by one. When it was zero on entry and another thread is waiting for it to become larger than zero again, wake up that thread.

### Semaphore Example

Semaphores are often used to guard resources with limited capacity, for example, a database server. In any situation where the size of the resource is fixed, you should use a bounded semaphore. Before spawning any worker threads, your main thread would initialize the semaphore:

```
maxconnections = 5
...
pool_sema = BoundedSemaphore(value=maxconnections)
```

Once spawned, worker threads call the semaphore's `acquire` and `release` methods when they need to connect to the server:

```
pool_sema.acquire()
conn = connectdb()
... use connection ...
conn.close()
pool_sema.release()
```

The use of a bounded semaphore reduces the chance that a programming error which causes the semaphore to be released more than it's acquired will go undetected.

## 16.2.6 Event Objects

This is one of the simplest mechanisms for communication between threads: one thread signals an event and other threads wait for it.

An event object manages an internal flag that can be set to true with the `set()` method and reset to false with the `clear()` method. The `wait()` method blocks until the flag is true.

**class** `threading.Event`

The internal flag is initially false.

**is\_set** ()

**isSet** ()

Return true if and only if the internal flag is true. Changed in version 2.6: The `is_set()` syntax is new.

**set** ()

Set the internal flag to true. All threads waiting for it to become true are awakened. Threads that call `wait()` once the flag is true will not block at all.

**clear** ()

Reset the internal flag to false. Subsequently, threads calling `wait()` will block until `set()` is called to set the internal flag to true again.

**wait** (*[timeout]*)

Block until the internal flag is true. If the internal flag is true on entry, return immediately. Otherwise, block until another thread calls `set()` to set the flag to true, or until the optional timeout occurs.

When the timeout argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

This method returns the internal flag on exit, so it will always return `True` except if a timeout is given and the operation times out. Changed in version 2.7: Previously, the method always returned `None`.

## 16.2.7 Timer Objects

This class represents an action that should be run only after a certain amount of time has passed — a timer. `Timer` is a subclass of `Thread` and as such also functions as an example of creating custom threads.

Timers are started, as with threads, by calling their `start()` method. The timer can be stopped (before its action has begun) by calling the `cancel()` method. The interval the timer will wait before executing its action may not be exactly the same as the interval specified by the user.

For example:

```
def hello():  
    print "hello, world"
```

```
t = Timer(30.0, hello)  
t.start() # after 30 seconds, "hello, world" will be printed
```

**class** `threading.Timer` (*interval, function, args=[ ], kwargs={}*)

Create a timer that will run *function* with arguments *args* and keyword arguments *kwargs*, after *interval* seconds have passed.

**cancel** ()

Stop the timer, and cancel the execution of the timer's action. This will only work if the timer is still in its waiting stage.

## 16.2.8 Using locks, conditions, and semaphores in the with statement

All of the objects provided by this module that have `acquire()` and `release()` methods can be used as context managers for a `with` statement. The `acquire()` method will be called when the block is entered, and `release()` will be called when the block is exited.

Currently, `Lock`, `RLock`, `Condition`, `Semaphore`, and `BoundedSemaphore` objects may be used as `with` statement context managers. For example:

```
import threading
```

```
some_rlock = threading.RLock()
```

```
with some_rlock:
    print "some_rlock is locked while this executes"
```

### 16.2.9 Importing in threaded code

While the import machinery is thread-safe, there are two key restrictions on threaded imports due to inherent limitations in the way that thread-safety is provided:

- Firstly, other than in the main module, an import should not have the side effect of spawning a new thread and then waiting for that thread in any way. Failing to abide by this restriction can lead to a deadlock if the spawned thread directly or indirectly attempts to import a module.
- Secondly, all import attempts must be completed before the interpreter starts shutting itself down. This can be most easily achieved by only performing imports from non-daemon threads created through the `threading` module. Daemon threads and threads created directly with the `thread` module will require some other form of synchronization to ensure they do not attempt imports after system shutdown has commenced. Failure to abide by this restriction will lead to intermittent exceptions and crashes during interpreter shutdown (as the late imports attempt to access machinery which is no longer in a valid state).

## 16.3 `thread` — Multiple threads of control

**Note:** The `thread` module has been renamed to `_thread` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3; however, you should consider using the high-level `threading` module instead.

This module provides low-level primitives for working with multiple threads (also called *light-weight processes* or *tasks*) — multiple threads of control sharing their global data space. For synchronization, simple locks (also called *mutexes* or *binary semaphores*) are provided. The `threading` module provides an easier to use and higher-level threading API built on top of this module.

The module is optional. It is supported on Windows, Linux, SGI IRIX, Solaris 2.x, as well as on systems that have a POSIX thread (a.k.a. “pthread”) implementation. For systems lacking the `thread` module, the `dummy_thread` module is available. It duplicates this module’s interface and can be used as a drop-in replacement.

It defines the following constant and functions:

**exception** `thread.error`

Raised on thread-specific errors.

`thread.LockType`

This is the type of lock objects.

`thread.start_new_thread` (*function*, *args*[, *kwargs* ])

Start a new thread and return its identifier. The thread executes the function *function* with the argument list *args* (which must be a tuple). The optional *kwargs* argument specifies a dictionary of keyword arguments. When the function returns, the thread silently exits. When the function terminates with an unhandled exception, a stack trace is printed and then the thread exits (but other threads continue to run).

`thread.interrupt_main()`

Raise a `KeyboardInterrupt` exception in the main thread. A subthread can use this function to interrupt the main thread. New in version 2.3.

`thread.exit()`

Raise the `SystemExit` exception. When not caught, this will cause the thread to exit silently.

`thread.allocate_lock()`

Return a new lock object. Methods of locks are described below. The lock is initially unlocked.

`thread.get_ident()`

Return the ‘thread identifier’ of the current thread. This is a nonzero integer. Its value has no direct meaning; it is intended as a magic cookie to be used e.g. to index a dictionary of thread-specific data. Thread identifiers may be recycled when a thread exits and another thread is created.

`thread.stack_size([size])`

Return the thread stack size used when creating new threads. The optional *size* argument specifies the stack size to be used for subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32kB). If changing the thread stack size is unsupported, the `error` exception is raised. If the specified stack size is invalid, a `ValueError` is raised and the stack size is unmodified. 32kB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32kB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4kB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads. New in version 2.5.

Lock objects have the following methods:

`lock.acquire([waitflag])`

Without the optional argument, this method acquires the lock unconditionally, if necessary waiting until it is released by another thread (only one thread at a time can acquire a lock — that’s their reason for existence). If the integer *waitflag* argument is present, the action depends on its value: if it is zero, the lock is only acquired if it can be acquired immediately without waiting, while if it is nonzero, the lock is acquired unconditionally as before. The return value is `True` if the lock is acquired successfully, `False` if not.

`lock.release()`

Releases the lock. The lock must have been acquired earlier, but not necessarily by the same thread.

`lock.locked()`

Return the status of the lock: `True` if it has been acquired by some thread, `False` if not.

In addition to these methods, lock objects can also be used via the `with` statement, e.g.:

```
import thread
```

```
a_lock = thread.allocate_lock()
```

```
with a_lock:
    print "a_lock is locked while this executes"
```

**Caveats:**

- Threads interact strangely with interrupts: the `KeyboardInterrupt` exception will be received by an arbitrary thread. (When the `signal` module is available, interrupts always go to the main thread.)
- Calling `sys.exit()` or raising the `SystemExit` exception is equivalent to calling `thread.exit()`.

- Not all built-in functions that may block waiting for I/O allow other threads to run. (The most popular ones (`time.sleep()`, `file.read()`, `select.select()`) work as expected.)
- It is not possible to interrupt the `acquire()` method on a lock — the `KeyboardInterrupt` exception will happen after the lock has been acquired.
- When the main thread exits, it is system defined whether the other threads survive. On SGI IRIX using the native thread implementation, they survive. On most other systems, they are killed without executing `try ... finally` clauses or executing object destructors.
- When the main thread exits, it does not do any of its usual cleanup (except that `try ... finally` clauses are honored), and the standard I/O files are not flushed.

## 16.4 `dummy_threading` — Drop-in replacement for the `threading` module

**Source code:** `Lib/dummy_threading.py`

This module provides a duplicate interface to the `threading` module. It is meant to be imported when the `thread` module is not provided on a platform.

Suggested usage is:

```
try:
    import threading as _threading
except ImportError:
    import dummy_threading as _threading
```

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.

## 16.5 `dummy_thread` — Drop-in replacement for the `thread` module

**Note:** The `dummy_thread` module has been renamed to `_dummy_thread` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3; however, you should consider using the higher-level `dummy_threading` module instead.

**Source code:** `Lib/dummy_thread.py`

This module provides a duplicate interface to the `thread` module. It is meant to be imported when the `thread` module is not provided on a platform.

Suggested usage is:

```
try:
    import thread as _thread
except ImportError:
    import dummy_thread as _thread
```

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.

## 16.6 multiprocessing — Process-based “threading” interface

New in version 2.6.

### 16.6.1 Introduction

`multiprocessing` is a package that supports spawning processes using an API similar to the `threading` module. The `multiprocessing` package offers both local and remote concurrency, effectively side-stepping the *Global Interpreter Lock* by using subprocesses instead of threads. Due to this, the `multiprocessing` module allows the programmer to fully leverage multiple processors on a given machine. It runs on both Unix and Windows.

**Warning:** Some of this package’s functionality requires a functioning shared semaphore implementation on the host operating system. Without one, the `multiprocessing.synchronize` module will be disabled, and attempts to import it will result in an `ImportError`. See [issue 3770](#) for additional information.

**Note:** Functionality within this package requires that the `__main__` module be importable by the children. This is covered in *Programming guidelines* however it is worth pointing out here. This means that some examples, such as the `multiprocessing.Pool` examples will not work in the interactive interpreter. For example:

```
>>> from multiprocessing import Pool
>>> p = Pool(5)
>>> def f(x):
...     return x*x
...
>>> p.map(f, [1,2,3])
Process PoolWorker-1:
Process PoolWorker-2:
Process PoolWorker-3:
Traceback (most recent call last):
AttributeError: 'module' object has no attribute 'f'
AttributeError: 'module' object has no attribute 'f'
AttributeError: 'module' object has no attribute 'f'
```

(If you try this it will actually output three full tracebacks interleaved in a semi-random fashion, and then you may have to stop the master process somehow.)

---

### The Process class

In `multiprocessing`, processes are spawned by creating a `Process` object and then calling its `start()` method. `Process` follows the API of `threading.Thread`. A trivial example of a multiprocess program is

```
from multiprocessing import Process

def f(name):
    print 'hello', name

if __name__ == '__main__':
    p = Process(target=f, args=('bob',))
    p.start()
    p.join()
```

To show the individual process IDs involved, here is an expanded example:

```

from multiprocessing import Process
import os

def info(title):
    print title
    print 'module name:', __name__
    if hasattr(os, 'getppid'): # only available on Unix
        print 'parent process:', os.getppid()
    print 'process id:', os.getpid()

def f(name):
    info('function f')
    print 'hello', name

if __name__ == '__main__':
    info('main line')
    p = Process(target=f, args=('bob',))
    p.start()
    p.join()

```

For an explanation of why (on Windows) the `if __name__ == '__main__':` part is necessary, see *Programming guidelines*.

## Exchanging objects between processes

`multiprocessing` supports two types of communication channel between processes:

### Queues

The `Queue` class is a near clone of `Queue.Queue`. For example:

```

from multiprocessing import Process, Queue

def f(q):
    q.put([42, None, 'hello'])

if __name__ == '__main__':
    q = Queue()
    p = Process(target=f, args=(q,))
    p.start()
    print q.get() # prints "[42, None, 'hello']"
    p.join()

```

Queues are thread and process safe.

### Pipes

The `Pipe()` function returns a pair of connection objects connected by a pipe which by default is duplex (two-way). For example:

```

from multiprocessing import Process, Pipe

def f(conn):
    conn.send([42, None, 'hello'])
    conn.close()

if __name__ == '__main__':

```

```
parent_conn, child_conn = Pipe()
p = Process(target=f, args=(child_conn,))
p.start()
print parent_conn.recv()    # prints "[42, None, 'hello']"
p.join()
```

The two connection objects returned by `Pipe()` represent the two ends of the pipe. Each connection object has `send()` and `recv()` methods (among others). Note that data in a pipe may become corrupted if two processes (or threads) try to read from or write to the *same* end of the pipe at the same time. Of course there is no risk of corruption from processes using different ends of the pipe at the same time.

### Synchronization between processes

`multiprocessing` contains equivalents of all the synchronization primitives from `threading`. For instance one can use a lock to ensure that only one process prints to standard output at a time:

```
from multiprocessing import Process, Lock

def f(l, i):
    l.acquire()
    print 'hello world', i
    l.release()

if __name__ == '__main__':
    lock = Lock()

    for num in range(10):
        Process(target=f, args=(lock, num)).start()
```

Without using the lock output from the different processes is liable to get all mixed up.

### Sharing state between processes

As mentioned above, when doing concurrent programming it is usually best to avoid using shared state as far as possible. This is particularly true when using multiple processes.

However, if you really do need to use some shared data then `multiprocessing` provides a couple of ways of doing so.

#### Shared memory

Data can be stored in a shared memory map using `Value` or `Array`. For example, the following code

```
from multiprocessing import Process, Value, Array

def f(n, a):
    n.value = 3.1415927
    for i in range(len(a)):
        a[i] = -a[i]

if __name__ == '__main__':
    num = Value('d', 0.0)
    arr = Array('i', range(10))

    p = Process(target=f, args=(num, arr))
    p.start()
```

```

p.join()

print num.value
print arr[:]

```

will print

```

3.1415927
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]

```

The 'd' and 'i' arguments used when creating `num` and `arr` are typecodes of the kind used by the `array` module: 'd' indicates a double precision float and 'i' indicates a signed integer. These shared objects will be process and thread-safe.

For more flexibility in using shared memory one can use the `multiprocessing.sharedctypes` module which supports the creation of arbitrary ctypes objects allocated from shared memory.

### Server process

A manager object returned by `Manager()` controls a server process which holds Python objects and allows other processes to manipulate them using proxies.

A manager returned by `Manager()` will support types `list`, `dict`, `Namespace`, `Lock`, `RLock`, `Semaphore`, `BoundedSemaphore`, `Condition`, `Event`, `Queue`, `Value` and `Array`. For example,

```

from multiprocessing import Process, Manager

def f(d, l):
    d[1] = '1'
    d['2'] = 2
    d[0.25] = None
    l.reverse()

if __name__ == '__main__':
    manager = Manager()

    d = manager.dict()
    l = manager.list(range(10))

    p = Process(target=f, args=(d, l))
    p.start()
    p.join()

    print d
    print l

```

will print

```

{0.25: None, 1: '1', '2': 2}
[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]

```

Server process managers are more flexible than using shared memory objects because they can be made to support arbitrary object types. Also, a single manager can be shared by processes on different computers over a network. They are, however, slower than using shared memory.

## Using a pool of workers

The `Pool` class represents a pool of worker processes. It has methods which allows tasks to be offloaded to the worker processes in a few different ways.

For example:

```
from multiprocessing import Pool

def f(x):
    return x*x

if __name__ == '__main__':
    pool = Pool(processes=4)           # start 4 worker processes
    result = pool.apply_async(f, [10]) # evaluate "f(10)" asynchronously
    print result.get(timeout=1)        # prints "100" unless your computer is *very* slow
    print pool.map(f, range(10))      # prints "[0, 1, 4, ..., 81]"
```

## 16.6.2 Reference

The `multiprocessing` package mostly replicates the API of the `threading` module.

### Process and exceptions

**class** `multiprocessing.Process` (*group=None, target=None, name=None, args=(), kwargs={}*)

Process objects represent activity that is run in a separate process. The `Process` class has equivalents of all the methods of `threading.Thread`.

The constructor should always be called with keyword arguments. *group* should always be `None`; it exists solely for compatibility with `threading.Thread`. *target* is the callable object to be invoked by the `run()` method. It defaults to `None`, meaning nothing is called. *name* is the process name. By default, a unique name is constructed of the form `'Process-N1:N2:...:Nk'` where `N1,N2,...,Nk` is a sequence of integers whose length is determined by the *generation* of the process. *args* is the argument tuple for the target invocation. *kwargs* is a dictionary of keyword arguments for the target invocation. By default, no arguments are passed to *target*.

If a subclass overrides the constructor, it must make sure it invokes the base class constructor (`Process.__init__()`) before doing anything else to the process.

**run()**

Method representing the process's activity.

You may override this method in a subclass. The standard `run()` method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the *args* and *kwargs* arguments, respectively.

**start()**

Start the process's activity.

This must be called at most once per process object. It arranges for the object's `run()` method to be invoked in a separate process.

**join([*timeout*])**

Block the calling thread until the process whose `join()` method is called terminates or until the optional timeout occurs.

If *timeout* is `None` then there is no timeout.

A process can be joined many times.

A process cannot join itself because this would cause a deadlock. It is an error to attempt to join a process before it has been started.

**name**

The process's name.

The name is a string used for identification purposes only. It has no semantics. Multiple processes may be given the same name. The initial name is set by the constructor.

**is\_alive()**

Return whether the process is alive.

Roughly, a process object is alive from the moment the `start()` method returns until the child process terminates.

**daemon**

The process's daemon flag, a Boolean value. This must be set before `start()` is called.

The initial value is inherited from the creating process.

When a process exits, it attempts to terminate all of its daemon child processes.

Note that a daemon process is not allowed to create child processes. Otherwise a daemon process would leave its children orphaned if it gets terminated when its parent process exits. Additionally, these are **not** Unix daemons or services, they are normal processes that will be terminated (and not joined) if non-daemon processes have exited.

In addition to the `Threading.Thread` API, `Process` objects also support the following attributes and methods:

**pid**

Return the process ID. Before the process is spawned, this will be `None`.

**exitcode**

The child's exit code. This will be `None` if the process has not yet terminated. A negative value `-N` indicates that the child was terminated by signal `N`.

**authkey**

The process's authentication key (a byte string).

When `multiprocessing` is initialized the main process is assigned a random string using `os.random()`.

When a `Process` object is created, it will inherit the authentication key of its parent process, although this may be changed by setting `authkey` to another byte string.

See *Authentication keys*.

**terminate()**

Terminate the process. On Unix this is done using the `SIGTERM` signal; on Windows `TerminateProcess()` is used. Note that exit handlers and finally clauses, etc., will not be executed.

Note that descendant processes of the process will *not* be terminated – they will simply become orphaned.

**Warning:** If this method is used when the associated process is using a pipe or queue then the pipe or queue is liable to become corrupted and may become unusable by other process. Similarly, if the process has acquired a lock or semaphore etc. then terminating it is liable to cause other processes to deadlock.

Note that the `start()`, `join()`, `is_alive()` and `exit_code` methods should only be called by the process that created the process object.

Example usage of some of the methods of `Process`:

```
>>> import multiprocessing, time, signal
>>> p = multiprocessing.Process(target=time.sleep, args=(1000,))
>>> print p, p.is_alive()
<Process(Process-1, initial)> False
>>> p.start()
>>> print p, p.is_alive()
<Process(Process-1, started)> True
>>> p.terminate()
>>> time.sleep(0.1)
>>> print p, p.is_alive()
<Process(Process-1, stopped[SIGTERM])> False
>>> p.exitcode == -signal.SIGTERM
True
```

### exception `multiprocessing.BufferTooShort`

Exception raised by `Connection.recv_bytes_into()` when the supplied buffer object is too small for the message read.

If `e` is an instance of `BufferTooShort` then `e.args[0]` will give the message as a byte string.

## Pipes and Queues

When using multiple processes, one generally uses message passing for communication between processes and avoids having to use any synchronization primitives like locks.

For passing messages one can use `Pipe()` (for a connection between two processes) or a queue (which allows multiple producers and consumers).

The `Queue`, `multiprocessing.queues.SimpleQueue` and `JoinableQueue` types are multi-producer, multi-consumer FIFO queues modelled on the `Queue.Queue` class in the standard library. They differ in that `Queue` lacks the `task_done()` and `join()` methods introduced into Python 2.5's `Queue.Queue` class.

If you use `JoinableQueue` then you **must** call `JoinableQueue.task_done()` for each task removed from the queue or else the semaphore used to count the number of unfinished tasks may eventually overflow, raising an exception.

Note that one can also create a shared queue by using a manager object – see *Managers*.

---

**Note:** `multiprocessing` uses the usual `Queue.Empty` and `Queue.Full` exceptions to signal a timeout. They are not available in the `multiprocessing` namespace so you need to import them from `Queue`.

---

**Warning:** If a process is killed using `Process.terminate()` or `os.kill()` while it is trying to use a `Queue`, then the data in the queue is likely to become corrupted. This may cause any other process to get an exception when it tries to use the queue later on.

**Warning:** As mentioned above, if a child process has put items on a queue (and it has not used `JoinableQueue.cancel_join_thread()`), then that process will not terminate until all buffered items have been flushed to the pipe.

This means that if you try joining that process you may get a deadlock unless you are sure that all items which have been put on the queue have been consumed. Similarly, if the child process is non-daemonic then the parent process may hang on exit when it tries to join all its non-daemonic children.

Note that a queue created using a manager does not have this issue. See *Programming guidelines*.

For an example of the usage of queues for interprocess communication see *Examples*.

`multiprocessing.Pipe([duplex])`

Returns a pair (`conn1`, `conn2`) of `Connection` objects representing the ends of a pipe.

If `duplex` is `True` (the default) then the pipe is bidirectional. If `duplex` is `False` then the pipe is unidirectional: `conn1` can only be used for receiving messages and `conn2` can only be used for sending messages.

**class** `multiprocessing.Queue([maxsize])`

Returns a process shared queue implemented using a pipe and a few locks/semaphores. When a process first puts an item on the queue a feeder thread is started which transfers objects from a buffer into the pipe.

The usual `Queue.Empty` and `Queue.Full` exceptions from the standard library's `Queue` module are raised to signal timeouts.

`Queue` implements all the methods of `Queue.Queue` except for `task_done()` and `join()`.

**qsize()**

Return the approximate size of the queue. Because of multithreading/multiprocessing semantics, this number is not reliable.

Note that this may raise `NotImplementedError` on Unix platforms like Mac OS X where `sem_getvalue()` is not implemented.

**empty()**

Return `True` if the queue is empty, `False` otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

**full()**

Return `True` if the queue is full, `False` otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

**put(obj[, block[, timeout]])**

Put `obj` into the queue. If the optional argument `block` is `True` (the default) and `timeout` is `None` (the default), block if necessary until a free slot is available. If `timeout` is a positive number, it blocks at most `timeout` seconds and raises the `Queue.Full` exception if no free slot was available within that time. Otherwise (`block` is `False`), put an item on the queue if a free slot is immediately available, else raise the `Queue.Full` exception (`timeout` is ignored in that case).

**put\_nowait(obj)**

Equivalent to `put(obj, False)`.

**get([block[, timeout]])**

Remove and return an item from the queue. If optional args `block` is `True` (the default) and `timeout` is `None` (the default), block if necessary until an item is available. If `timeout` is a positive number, it blocks at most `timeout` seconds and raises the `Queue.Empty` exception if no item was available within that time. Otherwise (`block` is `False`), return an item if one is immediately available, else raise the `Queue.Empty` exception (`timeout` is ignored in that case).

**get\_nowait()**

**get\_no\_wait()**

Equivalent to `get(False)`.

`Queue` has a few additional methods not found in `Queue.Queue`. These methods are usually unnecessary for most code:

**close()**

Indicate that no more data will be put on this queue by the current process. The background thread will quit once it has flushed all buffered data to the pipe. This is called automatically when the queue is garbage collected.

**join\_thread()**

Join the background thread. This can only be used after `close()` has been called. It blocks until the

background thread exits, ensuring that all data in the buffer has been flushed to the pipe.

By default if a process is not the creator of the queue then on exit it will attempt to join the queue's background thread. The process can call `cancel_join_thread()` to make `join_thread()` do nothing.

**cancel\_join\_thread()**

Prevent `join_thread()` from blocking. In particular, this prevents the background thread from being joined automatically when the process exits – see `join_thread()`.

**class multiprocessing.queues.SimpleQueue**

It is a simplified `Queue` type, very close to a locked `Pipe`.

**empty()**

Return `True` if the queue is empty, `False` otherwise.

**get()**

Remove and return an item from the queue.

**put(item)**

Put *item* into the queue.

**class multiprocessing.JoinableQueue([maxsize])**

`JoinableQueue`, a `Queue` subclass, is a queue which additionally has `task_done()` and `join()` methods.

**task\_done()**

Indicate that a formerly enqueued task is complete. Used by queue consumer threads. For each `get()` used to fetch a task, a subsequent call to `task_done()` tells the queue that the processing on the task is complete.

If a `join()` is currently blocking, it will resume when all items have been processed (meaning that a `task_done()` call was received for every item that had been `put()` into the queue).

Raises a `ValueError` if called more times than there were items placed in the queue.

**join()**

Block until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls `task_done()` to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, `join()` unblocks.

## Miscellaneous

`multiprocessing.active_children()`

Return list of all live children of the current process.

Calling this has the side affect of “joining” any processes which have already finished.

`multiprocessing.cpu_count()`

Return the number of CPUs in the system. May raise `NotImplementedError`.

`multiprocessing.current_process()`

Return the `Process` object corresponding to the current process.

An analogue of `threading.current_thread()`.

`multiprocessing.freeze_support()`

Add support for when a program which uses `multiprocessing` has been frozen to produce a Windows executable. (Has been tested with `py2exe`, `PyInstaller` and `cx_Freeze`.)

One needs to call this function straight after the `if __name__ == '__main__':` line of the main module. For example:

```
from multiprocessing import Process, freeze_support

def f():
    print 'hello world!'

if __name__ == '__main__':
    freeze_support()
    Process(target=f).start()
```

If the `freeze_support()` line is omitted then trying to run the frozen executable will raise `RuntimeError`.

If the module is being run normally by the Python interpreter then `freeze_support()` has no effect.

`multiprocessing.set_executable()`

Sets the path of the Python interpreter to use when starting a child process. (By default `sys.executable` is used). Embedders will probably need to do some thing like

```
set_executable(os.path.join(sys.exec_prefix, 'pythonw.exe'))
```

before they can create child processes. (Windows only)

---

**Note:** `multiprocessing` contains no analogues of `threading.active_count()`, `threading.enumerate()`, `threading.settrace()`, `threading.setprofile()`, `threading.Timer`, or `threading.local`.

---

## Connection Objects

Connection objects allow the sending and receiving of picklable objects or strings. They can be thought of as message oriented connected sockets.

Connection objects are usually created using `Pipe()` – see also *Listeners and Clients*.

**class** `multiprocessing.Connection`

**send** (*obj*)

Send an object to the other end of the connection which should be read using `recv()`.

The object must be picklable. Very large pickles (approximately 32 MB+, though it depends on the OS) may raise a `ValueError` exception.

**recv** ()

Return an object sent from the other end of the connection using `send()`. Blocks until there its something to receive. Raises `EOFError` if there is nothing left to receive and the other end was closed.

**fileno** ()

Return the file descriptor or handle used by the connection.

**close** ()

Close the connection.

This is called automatically when the connection is garbage collected.

**poll** (*[timeout]*)

Return whether there is any data available to be read.

If *timeout* is not specified then it will return immediately. If *timeout* is a number then this specifies the maximum time in seconds to block. If *timeout* is `None` then an infinite timeout is used.

**send\_bytes** (*buffer* [*, offset* [*, size* ] ])

Send byte data from an object supporting the buffer interface as a complete message.

If *offset* is given then data is read from that position in *buffer*. If *size* is given then that many bytes will be read from *buffer*. Very large buffers (approximately 32 MB+, though it depends on the OS) may raise a `ValueError` exception

**recv\_bytes** (*[maxlength]*)

Return a complete message of byte data sent from the other end of the connection as a string. Blocks until there is something to receive. Raises `EOFError` if there is nothing left to receive and the other end has closed.

If *maxlength* is specified and the message is longer than *maxlength* then `IOError` is raised and the connection will no longer be readable.

**recv\_bytes\_into** (*buffer* [*, offset* ])

Read into *buffer* a complete message of byte data sent from the other end of the connection and return the number of bytes in the message. Blocks until there is something to receive. Raises `EOFError` if there is nothing left to receive and the other end was closed.

*buffer* must be an object satisfying the writable buffer interface. If *offset* is given then the message will be written into the buffer from that position. Offset must be a non-negative integer less than the length of *buffer* (in bytes).

If the buffer is too short then a `BufferTooShort` exception is raised and the complete message is available as `e.args[0]` where `e` is the exception instance.

For example:

```
>>> from multiprocessing import Pipe
>>> a, b = Pipe()
>>> a.send([1, 'hello', None])
>>> b.recv()
[1, 'hello', None]
>>> b.send_bytes('thank you')
>>> a.recv_bytes()
'thank you'
>>> import array
>>> arr1 = array.array('i', range(5))
>>> arr2 = array.array('i', [0] * 10)
>>> a.send_bytes(arr1)
>>> count = b.recv_bytes_into(arr2)
>>> assert count == len(arr1) * arr1.itemsize
>>> arr2
array('i', [0, 1, 2, 3, 4, 0, 0, 0, 0, 0])
```

**Warning:** The `Connection.recv()` method automatically unpickles the data it receives, which can be a security risk unless you can trust the process which sent the message.

Therefore, unless the connection object was produced using `Pipe()` you should only use the `recv()` and `send()` methods after performing some sort of authentication. See *Authentication keys*.

**Warning:** If a process is killed while it is trying to read or write to a pipe then the data in the pipe is likely to become corrupted, because it may become impossible to be sure where the message boundaries lie.

## Synchronization primitives

Generally synchronization primitives are not as necessary in a multiprocess program as they are in a multithreaded program. See the documentation for `threading` module.

Note that one can also create synchronization primitives by using a manager object – see *Managers*.

**class** `multiprocessing.BoundedSemaphore` (`[value]`)

A bounded semaphore object: a clone of `threading.BoundedSemaphore`.

(On Mac OS X, this is indistinguishable from `Semaphore` because `sem_getvalue()` is not implemented on that platform).

**class** `multiprocessing.Condition` (`[lock]`)

A condition variable: a clone of `threading.Condition`.

If `lock` is specified then it should be a `Lock` or `RLock` object from `multiprocessing`.

**class** `multiprocessing.Event`

A clone of `threading.Event`. This method returns the state of the internal semaphore on exit, so it will always return `True` except if a timeout is given and the operation times out. Changed in version 2.7: Previously, the method always returned `None`.

**class** `multiprocessing.Lock`

A non-recursive lock object: a clone of `threading.Lock`.

**class** `multiprocessing.RLock`

A recursive lock object: a clone of `threading.RLock`.

**class** `multiprocessing.Semaphore` (`[value]`)

A semaphore object: a clone of `threading.Semaphore`.

---

**Note:** The `acquire()` method of `BoundedSemaphore`, `Lock`, `RLock` and `Semaphore` has a timeout parameter not supported by the equivalents in `threading`. The signature is `acquire(block=True, timeout=None)` with keyword parameters being acceptable. If `block` is `True` and `timeout` is not `None` then it specifies a timeout in seconds. If `block` is `False` then `timeout` is ignored.

On Mac OS X, `sem_timedwait` is unsupported, so calling `acquire()` with a timeout will emulate that function's behavior using a sleeping loop.

---

**Note:** If the SIGINT signal generated by Ctrl-C arrives while the main thread is blocked by a call to `BoundedSemaphore.acquire()`, `Lock.acquire()`, `RLock.acquire()`, `Semaphore.acquire()`, `Condition.acquire()` or `Condition.wait()` then the call will be immediately interrupted and `KeyboardInterrupt` will be raised.

This differs from the behaviour of `threading` where SIGINT will be ignored while the equivalent blocking calls are in progress.

---

## Shared ctypes Objects

It is possible to create shared objects using shared memory which can be inherited by child processes.

`multiprocessing.Value` (*typecode\_or\_type*, \**args* [, *lock* ])

Return a `ctypes` object allocated from shared memory. By default the return value is actually a synchronized wrapper for the object.

*typecode\_or\_type* determines the type of the returned object: it is either a `ctypes` type or a one character typecode of the kind used by the `array` module. \**args* is passed on to the constructor for the type.

If *lock* is `True` (the default) then a new lock object is created to synchronize access to the value. If *lock* is a `Lock` or `RLock` object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that *lock* is a keyword-only argument.

`multiprocessing.Array` (*typecode\_or\_type*, *size\_or\_initializer*, \*, *lock=True*)

Return a `ctypes` array allocated from shared memory. By default the return value is actually a synchronized wrapper for the array.

*typecode\_or\_type* determines the type of the elements of the returned array: it is either a `ctypes` type or a one character typecode of the kind used by the `array` module. If *size\_or\_initializer* is an integer, then it determines the length of the array, and the array will be initially zeroed. Otherwise, *size\_or\_initializer* is a sequence which is used to initialize the array and whose length determines the length of the array.

If *lock* is `True` (the default) then a new lock object is created to synchronize access to the value. If *lock* is a `Lock` or `RLock` object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that *lock* is a keyword only argument.

Note that an array of `ctypes.c_char` has *value* and *raw* attributes which allow one to use it to store and retrieve strings.

### The `multiprocessing.sharedctypes` module

The `multiprocessing.sharedctypes` module provides functions for allocating `ctypes` objects from shared memory which can be inherited by child processes.

---

**Note:** Although it is possible to store a pointer in shared memory remember that this will refer to a location in the address space of a specific process. However, the pointer is quite likely to be invalid in the context of a second process and trying to dereference the pointer from the second process may cause a crash.

---

`multiprocessing.sharedctypes.RawArray` (*typecode\_or\_type*, *size\_or\_initializer*)

Return a `ctypes` array allocated from shared memory.

*typecode\_or\_type* determines the type of the elements of the returned array: it is either a `ctypes` type or a one character typecode of the kind used by the `array` module. If *size\_or\_initializer* is an integer then it determines the length of the array, and the array will be initially zeroed. Otherwise *size\_or\_initializer* is a sequence which is used to initialize the array and whose length determines the length of the array.

Note that setting and getting an element is potentially non-atomic – use `Array()` instead to make sure that access is automatically synchronized using a lock.

`multiprocessing.sharedctypes.RawValue` (*typecode\_or\_type*, \**args*)

Return a `ctypes` object allocated from shared memory.

*typecode\_or\_type* determines the type of the returned object: it is either a `ctypes` type or a one character typecode of the kind used by the `array` module. \**args* is passed on to the constructor for the type.

Note that setting and getting the value is potentially non-atomic – use `Value()` instead to make sure that access is automatically synchronized using a lock.

Note that an array of `ctypes.c_char` has `value` and `raw` attributes which allow one to use it to store and retrieve strings – see documentation for `ctypes`.

`multiprocessing.sharedctypes.Array` (*typecode\_or\_type*, *size\_or\_initializer*, *\*args* [, *lock* ])

The same as `RawArray()` except that depending on the value of `lock` a process-safe synchronization wrapper may be returned instead of a raw ctypes array.

If `lock` is `True` (the default) then a new lock object is created to synchronize access to the value. If `lock` is a `Lock` or `RLock` object then that will be used to synchronize access to the value. If `lock` is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that `lock` is a keyword-only argument.

`multiprocessing.sharedctypes.Value` (*typecode\_or\_type*, *\*args* [, *lock* ])

The same as `RawValue()` except that depending on the value of `lock` a process-safe synchronization wrapper may be returned instead of a raw ctypes object.

If `lock` is `True` (the default) then a new lock object is created to synchronize access to the value. If `lock` is a `Lock` or `RLock` object then that will be used to synchronize access to the value. If `lock` is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that `lock` is a keyword-only argument.

`multiprocessing.sharedctypes.copy` (*obj*)

Return a ctypes object allocated from shared memory which is a copy of the ctypes object *obj*.

`multiprocessing.sharedctypes.synchronized` (*obj* [, *lock* ])

Return a process-safe wrapper object for a ctypes object which uses `lock` to synchronize access. If `lock` is `None` (the default) then a `multiprocessing.RLock` object is created automatically.

A synchronized wrapper will have two methods in addition to those of the object it wraps: `get_obj()` returns the wrapped object and `get_lock()` returns the lock object used for synchronization.

Note that accessing the ctypes object through the wrapper can be a lot slower than accessing the raw ctypes object.

The table below compares the syntax for creating shared ctypes objects from shared memory with the normal ctypes syntax. (In the table `MyStruct` is some subclass of `ctypes.Structure`.)

ctypes	sharedctypes using type	sharedctypes using typecode
<code>c_double(2.4)</code>	<code>RawValue(c_double, 2.4)</code>	<code>RawValue('d', 2.4)</code>
<code>MyStruct(4, 6)</code>	<code>RawValue(MyStruct, 4, 6)</code>	
<code>(c_short * 7)()</code>	<code>RawArray(c_short, 7)</code>	<code>RawArray('h', 7)</code>
<code>(c_int * 3)(9, 2, 8)</code>	<code>RawArray(c_int, (9, 2, 8))</code>	<code>RawArray('i', (9, 2, 8))</code>

Below is an example where a number of ctypes objects are modified by a child process:

```
from multiprocessing import Process, Lock
from multiprocessing.sharedctypes import Value, Array
from ctypes import Structure, c_double

class Point(Structure):
    _fields_ = [('x', c_double), ('y', c_double)]

def modify(n, x, s, A):
    n.value += 2
    x.value += 2
    s.value = s.value.upper()
    for a in A:
        a.x += 2
        a.y += 2
```

```
if __name__ == '__main__':
    lock = Lock()

    n = Value('i', 7)
    x = Value(c_double, 1.0/3.0, lock=False)
    s = Array('c', 'hello world', lock=lock)
    A = Array(Point, [(1.875,-6.25), (-5.75,2.0), (2.375,9.5)], lock=lock)

    p = Process(target=modify, args=(n, x, s, A))
    p.start()
    p.join()

    print n.value
    print x.value
    print s.value
    print [(a.x, a.y) for a in A]
```

The results printed are

```
49
0.11111111111111111
HELLO WORLD
[(3.515625, 39.0625), (33.0625, 4.0), (5.640625, 90.25)]
```

## Managers

Managers provide a way to create data which can be shared between different processes. A manager object controls a server process which manages *shared objects*. Other processes can access the shared objects by using proxies.

`multiprocessing.Manager()`

Returns a started `SyncManager` object which can be used for sharing objects between processes. The returned manager object corresponds to a spawned child process and has methods which will create shared objects and return corresponding proxies.

Manager processes will be shutdown as soon as they are garbage collected or their parent process exits. The manager classes are defined in the `multiprocessing.managers` module:

**class** `multiprocessing.managers.BaseManager` (`[address[, authkey]]`)

Create a `BaseManager` object.

Once created one should call `start()` or `get_server().serve_forever()` to ensure that the manager object refers to a started manager process.

*address* is the address on which the manager process listens for new connections. If *address* is `None` then an arbitrary one is chosen.

*authkey* is the authentication key which will be used to check the validity of incoming connections to the server process. If *authkey* is `None` then `current_process().authkey`. Otherwise *authkey* is used and it must be a string.

**start** (`[initializer[, initargs]]`)

Start a subprocess to start the manager. If *initializer* is not `None` then the subprocess will call `initializer(*initargs)` when it starts.

**get\_server** ()

Returns a `Server` object which represents the actual server under the control of the `Manager`. The `Server` object supports the `serve_forever()` method:

```
>>> from multiprocessing.managers import BaseManager
>>> manager = BaseManager(address=(' ', 50000), authkey='abc')
>>> server = manager.get_server()
>>> server.serve_forever()
```

Server additionally has an `address` attribute.

#### **connect ()**

Connect a local manager object to a remote manager process:

```
>>> from multiprocessing.managers import BaseManager
>>> m = BaseManager(address=('127.0.0.1', 5000), authkey='abc')
>>> m.connect()
```

#### **shutdown ()**

Stop the process used by the manager. This is only available if `start ()` has been used to start the server process.

This can be called multiple times.

#### **register (typeid[, callable[, proxytype[, exposed[, method\_to\_typeid[, create\_method ]]]]])**

A classmethod which can be used for registering a type or callable with the manager class.

*typeid* is a “type identifier” which is used to identify a particular type of shared object. This must be a string.

*callable* is a callable used for creating objects for this type identifier. If a manager instance will be created using the `from_address ()` classmethod or if the *create\_method* argument is `False` then this can be left as `None`.

*proxytype* is a subclass of `BaseProxy` which is used to create proxies for shared objects with this *typeid*. If `None` then a proxy class is created automatically.

*exposed* is used to specify a sequence of method names which proxies for this *typeid* should be allowed to access using `BaseProxy._callMethod ()`. (If *exposed* is `None` then `proxytype._exposed_` is used instead if it exists.) In the case where no exposed list is specified, all “public methods” of the shared object will be accessible. (Here a “public method” means any attribute which has a `__call__ ()` method and whose name does not begin with `'_'`.)

*method\_to\_typeid* is a mapping used to specify the return type of those exposed methods which should return a proxy. It maps method names to *typeid* strings. (If *method\_to\_typeid* is `None` then `proxytype._method_to_typeid_` is used instead if it exists.) If a method’s name is not a key of this mapping or if the mapping is `None` then the object returned by the method will be copied by value.

*create\_method* determines whether a method should be created with name *typeid* which can be used to tell the server process to create a new shared object and return a proxy for it. By default it is `True`.

`BaseManager` instances also have one read-only property:

#### **address**

The address used by the manager.

#### **class multiprocessing.managers.SyncManager**

A subclass of `BaseManager` which can be used for the synchronization of processes. Objects of this type are returned by `multiprocessing.Manager ()`.

It also supports creation of shared lists and dictionaries.

#### **BoundedSemaphore ([value])**

Create a shared `threading.BoundedSemaphore` object and return a proxy for it.

**Condition** (*[lock]*)

Create a shared `threading.Condition` object and return a proxy for it.

If *lock* is supplied then it should be a proxy for a `threading.Lock` or `threading.RLock` object.

**Event** ()

Create a shared `threading.Event` object and return a proxy for it.

**Lock** ()

Create a shared `threading.Lock` object and return a proxy for it.

**Namespace** ()

Create a shared `Namespace` object and return a proxy for it.

**Queue** (*[maxsize]*)

Create a shared `Queue.Queue` object and return a proxy for it.

**RLock** ()

Create a shared `threading.RLock` object and return a proxy for it.

**Semaphore** (*[value]*)

Create a shared `threading.Semaphore` object and return a proxy for it.

**Array** (*typecode, sequence*)

Create an array and return a proxy for it.

**Value** (*typecode, value*)

Create an object with a writable `value` attribute and return a proxy for it.

**dict** ()

**dict** (*mapping*)

**dict** (*sequence*)

Create a shared `dict` object and return a proxy for it.

**list** ()

**list** (*sequence*)

Create a shared `list` object and return a proxy for it.

---

**Note:** Modifications to mutable values or items in `dict` and `list` proxies will not be propagated through the manager, because the proxy has no way of knowing when its values or items are modified. To modify such an item, you can re-assign the modified object to the container proxy:

```
# create a list proxy and append a mutable object (a dictionary)
lproxy = manager.list()
lproxy.append({})
# now mutate the dictionary
d = lproxy[0]
d['a'] = 1
d['b'] = 2
# at this point, the changes to d are not yet synced, but by
# reassigning the dictionary, the proxy is notified of the change
lproxy[0] = d
```

---

## Namespace objects

A namespace object has no public methods, but does have writable attributes. Its representation shows the values of its attributes.

However, when using a proxy for a namespace object, an attribute beginning with `'_'` will be an attribute of the proxy and not an attribute of the referent:

```
>>> manager = multiprocessing.Manager()
>>> Global = manager.Namespace()
>>> Global.x = 10
>>> Global.y = 'hello'
>>> Global._z = 12.3      # this is an attribute of the proxy
>>> print Global
Namespace(x=10, y='hello')
```

### Customized managers

To create one's own manager, one creates a subclass of `BaseManager` and uses the `register()` classmethod to register new types or callables with the manager class. For example:

```
from multiprocessing.managers import BaseManager

class MathsClass(object):
    def add(self, x, y):
        return x + y
    def mul(self, x, y):
        return x * y

class MyManager(BaseManager):
    pass
```

```
MyManager.register('Maths', MathsClass)
```

```
if __name__ == '__main__':
    manager = MyManager()
    manager.start()
    maths = manager.Maths()
    print maths.add(4, 3)      # prints 7
    print maths.mul(7, 8)     # prints 56
```

### Using a remote manager

It is possible to run a manager server on one machine and have clients use it from other machines (assuming that the firewalls involved allow it).

Running the following commands creates a server for a single shared queue which remote clients can access:

```
>>> from multiprocessing.managers import BaseManager
>>> import Queue
>>> queue = Queue.Queue()
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue', callable=lambda:queue)
>>> m = QueueManager(address=(' ', 50000), authkey='abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

One client can access the server as follows:

```
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000), authkey='abracadabra')
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.put('hello')
```

Another client can also use it:

```
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000), authkey='abracadabra')
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.get()
'hello'
```

Local processes can also access that queue, using the code from above on the client to access it remotely:

```
>>> from multiprocessing import Process, Queue
>>> from multiprocessing.managers import BaseManager
>>> class Worker(Process):
...     def __init__(self, q):
...         self.q = q
...         super(Worker, self).__init__()
...     def run(self):
...         self.q.put('local hello')
...
>>> queue = Queue()
>>> w = Worker(queue)
>>> w.start()
>>> class QueueManager(BaseManager): pass
...
>>> QueueManager.register('get_queue', callable=lambda: queue)
>>> m = QueueManager(address='', 50000), authkey='abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

## Proxy Objects

A proxy is an object which *refers* to a shared object which lives (presumably) in a different process. The shared object is said to be the *referent* of the proxy. Multiple proxy objects may have the same referent.

A proxy object has methods which invoke corresponding methods of its referent (although not every method of the referent will necessarily be available through the proxy). A proxy can usually be used in most of the same ways that its referent can:

```
>>> from multiprocessing import Manager
>>> manager = Manager()
>>> l = manager.list([i*i for i in range(10)])
>>> print l
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
>>> print repr(l)
<ListProxy object, typeid 'list' at 0x...>
```

```
>>> l[4]
16
>>> l[2:5]
[4, 9, 16]
```

Notice that applying `str()` to a proxy will return the representation of the referent, whereas applying `repr()` will return the representation of the proxy.

An important feature of proxy objects is that they are picklable so they can be passed between processes. Note, however, that if a proxy is sent to the corresponding manager's process then unpickling it will produce the referent itself. This means, for example, that one shared object can contain a second:

```
>>> a = manager.list()
>>> b = manager.list()
>>> a.append(b)           # referent of a now contains referent of b
>>> print a, b
[[]] []
>>> b.append('hello')
>>> print a, b
[['hello']] ['hello']
```

**Note:** The proxy types in `multiprocessing` do nothing to support comparisons by value. So, for instance, we have:

```
>>> manager.list([1,2,3]) == [1,2,3]
False
```

One should just use a copy of the referent instead when making comparisons.

---

#### **class** `multiprocessing.managers.BaseProxy`

Proxy objects are instances of subclasses of `BaseProxy`.

**`_callmethod`** (*methodname* [, *args* [, *kwargs* ]])

Call and return the result of a method of the proxy's referent.

If `proxy` is a proxy whose referent is `obj` then the expression

```
proxy._callmethod(methodname, args, kwargs)
```

will evaluate the expression

```
getattr(obj, methodname)(*args, **kwargs)
```

in the manager's process.

The returned value will be a copy of the result of the call or a proxy to a new shared object – see documentation for the *method\_to\_typeid* argument of `BaseManager.register()`.

If an exception is raised by the call, then is re-raised by `_callmethod()`. If some other exception is raised in the manager's process then this is converted into a `RemoteError` exception and is raised by `_callmethod()`.

Note in particular that an exception will be raised if *methodname* has not been *exposed*

An example of the usage of `_callmethod()`:

```
>>> l = manager.list(range(10))
>>> l._callmethod('__len__')
10
```

```
>>> l.__callmethod('__getslice__', (2, 7)) # equiv to 'l[2:7]'
[2, 3, 4, 5, 6]
>>> l.__callmethod('__getitem__', (20,)) # equiv to 'l[20]'
Traceback (most recent call last):
...
IndexError: list index out of range
```

**`__getvalue()`**

Return a copy of the referent.

If the referent is unpicklable then this will raise an exception.

**`__repr__()`**

Return a representation of the proxy object.

**`__str__()`**

Return the representation of the referent.

### Cleanup

A proxy object uses a weakref callback so that when it gets garbage collected it deregisters itself from the manager which owns its referent.

A shared object gets deleted from the manager process when there are no longer any proxies referring to it.

### Process Pools

One can create a pool of processes which will carry out tasks submitted to it with the `Pool` class.

**class** `multiprocessing.Pool` (`[processes[, initializer[, initargs[, maxtasksperchild]]]`)

A process pool object which controls a pool of worker processes to which jobs can be submitted. It supports asynchronous results with timeouts and callbacks and has a parallel map implementation.

`processes` is the number of worker processes to use. If `processes` is `None` then the number returned by `cpu_count()` is used. If `initializer` is not `None` then each worker process will call `initializer(*initargs)` when it starts. New in version 2.7: `maxtasksperchild` is the number of tasks a worker process can complete before it will exit and be replaced with a fresh worker process, to enable unused resources to be freed. The default `maxtasksperchild` is `None`, which means worker processes will live as long as the pool.

---

**Note:** Worker processes within a `Pool` typically live for the complete duration of the `Pool`'s work queue. A frequent pattern found in other systems (such as Apache, `mod_wsgi`, etc) to free resources held by workers is to allow a worker within a pool to complete only a set amount of work before being exiting, being cleaned up and a new process spawned to replace the old one. The `maxtasksperchild` argument to the `Pool` exposes this ability to the end user.

---

**apply** (`func` [`args` [`kwds`]])

Equivalent of the `apply()` built-in function. It blocks until the result is ready, so `apply_async()` is better suited for performing work in parallel. Additionally, `func` is only executed in one of the workers of the pool.

**apply\_async** (`func` [`args` [`kwds` [`callback`]]])

A variant of the `apply()` method which returns a result object.

If *callback* is specified then it should be a callable which accepts a single argument. When the result becomes ready *callback* is applied to it (unless the call failed). *callback* should complete immediately since otherwise the thread which handles the results will get blocked.

**map** (*func*, *iterable*[, *chunksize* ])

A parallel equivalent of the `map()` built-in function (it supports only one *iterable* argument though). It blocks until the result is ready.

This method chops the iterable into a number of chunks which it submits to the process pool as separate tasks. The (approximate) size of these chunks can be specified by setting *chunksize* to a positive integer.

**map\_async** (*func*, *iterable*[, *chunksize*[, *callback* ] ])

A variant of the `map()` method which returns a result object.

If *callback* is specified then it should be a callable which accepts a single argument. When the result becomes ready *callback* is applied to it (unless the call failed). *callback* should complete immediately since otherwise the thread which handles the results will get blocked.

**imap** (*func*, *iterable*[, *chunksize* ])

An equivalent of `itertools.imap()`.

The *chunksize* argument is the same as the one used by the `map()` method. For very long iterables using a large value for *chunksize* can make the job complete **much** faster than using the default value of 1.

Also if *chunksize* is 1 then the `next()` method of the iterator returned by the `imap()` method has an optional *timeout* parameter: `next(timeout)` will raise `multiprocessing.TimeoutError` if the result cannot be returned within *timeout* seconds.

**imap\_unordered** (*func*, *iterable*[, *chunksize* ])

The same as `imap()` except that the ordering of the results from the returned iterator should be considered arbitrary. (Only when there is only one worker process is the order guaranteed to be “correct”).

**close** ()

Prevents any more tasks from being submitted to the pool. Once all the tasks have been completed the worker processes will exit.

**terminate** ()

Stops the worker processes immediately without completing outstanding work. When the pool object is garbage collected `terminate()` will be called immediately.

**join** ()

Wait for the worker processes to exit. One must call `close()` or `terminate()` before using `join()`.

**class** `multiprocessing.pool.AsyncResult`

The class of the result returned by `Pool.apply_async()` and `Pool.map_async()`.

**get** ([*timeout* ])

Return the result when it arrives. If *timeout* is not `None` and the result does not arrive within *timeout* seconds then `multiprocessing.TimeoutError` is raised. If the remote call raised an exception then that exception will be reraised by `get()`.

**wait** ([*timeout* ])

Wait until the result is available or until *timeout* seconds pass.

**ready** ()

Return whether the call has completed.

**successful** ()

Return whether the call completed without raising an exception. Will raise `AssertionError` if the result is not ready.

The following example demonstrates the use of a pool:

```

from multiprocessing import Pool

def f(x):
    return x*x

if __name__ == '__main__':
    pool = Pool(processes=4)           # start 4 worker processes

    result = pool.apply_async(f, (10,)) # evaluate "f(10)" asynchronously
    print result.get(timeout=1)        # prints "100" unless your computer is *very* slow

    print pool.map(f, range(10))      # prints "[0, 1, 4, ..., 81]"

    it = pool.imap(f, range(10))
    print it.next()                   # prints "0"
    print it.next()                   # prints "1"
    print it.next(timeout=1)          # prints "4" unless your computer is *very* slow

    import time
    result = pool.apply_async(time.sleep, (10,))
    print result.get(timeout=1)        # raises TimeoutError

```

## Listeners and Clients

Usually message passing between processes is done using queues or by using `Connection` objects returned by `Pipe()`.

However, the `multiprocessing.connection` module allows some extra flexibility. It basically gives a high level message oriented API for dealing with sockets or Windows named pipes, and also has support for *digest authentication* using the `hmac` module.

`multiprocessing.connection.deliver_challenge` (*connection*, *authkey*)

Send a randomly generated message to the other end of the connection and wait for a reply.

If the reply matches the digest of the message using *authkey* as the key then a welcome message is sent to the other end of the connection. Otherwise `AuthenticationError` is raised.

`multiprocessing.connection.answerChallenge` (*connection*, *authkey*)

Receive a message, calculate the digest of the message using *authkey* as the key, and then send the digest back.

If a welcome message is not received, then `AuthenticationError` is raised.

`multiprocessing.connection.Client` (*address*[, *family*[, *authenticate*[, *authkey*]]])

Attempt to set up a connection to the listener which is using address *address*, returning a `Connection`.

The type of the connection is determined by *family* argument, but this can generally be omitted since it can usually be inferred from the format of *address*. (See *Address Formats*)

If *authenticate* is `True` or *authkey* is a string then digest authentication is used. The key used for authentication will be either *authkey* or `current_process().authkey` if *authkey* is `None`. If authentication fails then `AuthenticationError` is raised. See *Authentication keys*.

`class multiprocessing.connection.Listener` (*[address*[, *family*[, *backlog*[, *authenticate*[, *authkey*]]]]])

A wrapper for a bound socket or Windows named pipe which is 'listening' for connections.

*address* is the address to be used by the bound socket or named pipe of the listener object.

**Note:** If an address of '0.0.0.0' is used, the address will not be a connectable end point on Windows. If you require a connectable end-point, you should use '127.0.0.1'.

*family* is the type of socket (or named pipe) to use. This can be one of the strings 'AF\_INET' (for a TCP socket), 'AF\_UNIX' (for a Unix domain socket) or 'AF\_PIPE' (for a Windows named pipe). Of these only the first is guaranteed to be available. If *family* is None then the family is inferred from the format of *address*. If *address* is also None then a default is chosen. This default is the family which is assumed to be the fastest available. See *Address Formats*. Note that if *family* is 'AF\_UNIX' and *address* is None then the socket will be created in a private temporary directory created using `tempfile.mkstemp()`.

If the listener object uses a socket then *backlog* (1 by default) is passed to the `listen()` method of the socket once it has been bound.

If *authenticate* is True (False by default) or *authkey* is not None then digest authentication is used.

If *authkey* is a string then it will be used as the authentication key; otherwise it must be None.

If *authkey* is None and *authenticate* is True then `current_process().authkey` is used as the authentication key. If *authkey* is None and *authenticate* is False then no authentication is done. If authentication fails then `AuthenticationError` is raised. See *Authentication keys*.

#### **accept()**

Accept a connection on the bound socket or named pipe of the listener object and return a `Connection` object. If authentication is attempted and fails, then `AuthenticationError` is raised.

#### **close()**

Close the bound socket or named pipe of the listener object. This is called automatically when the listener is garbage collected. However it is advisable to call it explicitly.

Listener objects have the following read-only properties:

#### **address**

The address which is being used by the Listener object.

#### **last\_accepted**

The address from which the last accepted connection came. If this is unavailable then it is None.

The module defines two exceptions:

#### **exception multiprocessing.connection.AuthenticationError**

Exception raised when there is an authentication error.

#### **Examples**

The following server code creates a listener which uses 'secret password' as an authentication key. It then waits for a connection and sends some data to the client:

```
from multiprocessing.connection import Listener
from array import array

address = ('localhost', 6000)      # family is deduced to be 'AF_INET'
listener = Listener(address, authkey='secret password')

conn = listener.accept()
print 'connection accepted from', listener.last_accepted

conn.send([2.25, None, 'junk', float])

conn.send_bytes('hello')

conn.send_bytes(array('i', [42, 1729]))
```

```
conn.close()
listener.close()
```

The following code connects to the server and receives some data from the server:

```
from multiprocessing.connection import Client
from array import array

address = ('localhost', 6000)
conn = Client(address, authkey='secret password')

print conn.recv()           # => [2.25, None, 'junk', float]

print conn.recv_bytes()     # => 'hello'

arr = array('i', [0, 0, 0, 0, 0])
print conn.recv_bytes_into(arr) # => 8
print arr                   # => array('i', [42, 1729, 0, 0, 0])

conn.close()
```

### Address Formats

- An `'AF_INET'` address is a tuple of the form `(hostname, port)` where *hostname* is a string and *port* is an integer.
- An `'AF_UNIX'` address is a string representing a filename on the filesystem.
- An `'AF_PIPE'` address is a string of the form `'r'\\.pipe\PipeName'`. To use `Client()` to connect to a named pipe on a remote computer called *ServerName* one should use an address of the form `'r'\\.ServerName\pipe\PipeName'` instead.

Note that any string beginning with two backslashes is assumed by default to be an `'AF_PIPE'` address rather than an `'AF_UNIX'` address.

### Authentication keys

When one uses `Connection.recv()`, the data received is automatically unpickled. Unfortunately unpickling data from an untrusted source is a security risk. Therefore `Listener` and `Client()` use the `hmac` module to provide digest authentication.

An authentication key is a string which can be thought of as a password: once a connection is established both ends will demand proof that the other knows the authentication key. (Demonstrating that both ends are using the same key does **not** involve sending the key over the connection.)

If authentication is requested but no authentication key is specified then the return value of `current_process().authkey` is used (see `Process`). This value will automatically be inherited by any `Process` object that the current process creates. This means that (by default) all processes of a multi-process program will share a single authentication key which can be used when setting up connections between themselves.

Suitable authentication keys can also be generated by using `os.urandom()`.

## Logging

Some support for logging is available. Note, however, that the `logging` package does not use process shared locks so it is possible (depending on the handler type) for messages from different processes to get mixed up.

`multiprocessing.get_logger()`

Returns the logger used by `multiprocessing`. If necessary, a new one will be created.

When first created the logger has level `logging.NOTSET` and no default handler. Messages sent to this logger will not by default propagate to the root logger.

Note that on Windows child processes will only inherit the level of the parent process's logger – any other customization of the logger will not be inherited.

`multiprocessing.log_to_stderr()`

This function performs a call to `get_logger()` but in addition to returning the logger created by `get_logger`, it adds a handler which sends output to `sys.stderr` using format `' [% (levelname) s / % (processName) s ] % (message) s '`.

Below is an example session with logging turned on:

```
>>> import multiprocessing, logging
>>> logger = multiprocessing.log_to_stderr()
>>> logger.setLevel(logging.INFO)
>>> logger.warning('doomed')
[WARNING/MainProcess] doomed
>>> m = multiprocessing.Manager()
[INFO/SyncManager-...] child process calling self.run()
[INFO/SyncManager-...] created temp directory /.../pymp-...
[INFO/SyncManager-...] manager serving at '/.../listener-...'
>>> del m
[INFO/MainProcess] sending shutdown message to manager
[INFO/SyncManager-...] manager exiting with exitcode 0
```

In addition to having these two logging functions, the `multiprocessing` also exposes two additional logging level attributes. These are `SUBWARNING` and `SUBDEBUG`. The table below illustrates where these fit in the normal level hierarchy.

Level	Numeric value
<code>SUBWARNING</code>	25
<code>SUBDEBUG</code>	5

For a full table of logging levels, see the `logging` module.

These additional logging levels are used primarily for certain debug messages within the `multiprocessing` module. Below is the same example as above, except with `SUBDEBUG` enabled:

```
>>> import multiprocessing, logging
>>> logger = multiprocessing.log_to_stderr()
>>> logger.setLevel(multiprocessing.SUBDEBUG)
>>> logger.warning('doomed')
[WARNING/MainProcess] doomed
>>> m = multiprocessing.Manager()
[INFO/SyncManager-...] child process calling self.run()
[INFO/SyncManager-...] created temp directory /.../pymp-...
[INFO/SyncManager-...] manager serving at '/.../pymp-djGBXN/listener-...'
>>> del m
[SUBDEBUG/MainProcess] finalizer calling ...
[INFO/MainProcess] sending shutdown message to manager
```

```
[DEBUG/SyncManager-...] manager received shutdown message
[SUBDEBUG/SyncManager-...] calling <Finalize object, callback=unlink, ...
[SUBDEBUG/SyncManager-...] finalizer calling <built-in function unlink> ...
[SUBDEBUG/SyncManager-...] calling <Finalize object, dead>
[SUBDEBUG/SyncManager-...] finalizer calling <function rmtree at 0x5aa730> ...
[INFO/SyncManager-...] manager exiting with exitcode 0
```

### The `multiprocessing.dummy` module

`multiprocessing.dummy` replicates the API of `multiprocessing` but is no more than a wrapper around the `threading` module.

## 16.6.3 Programming guidelines

There are certain guidelines and idioms which should be adhered to when using `multiprocessing`.

### All platforms

#### Avoid shared state

As far as possible one should try to avoid shifting large amounts of data between processes.

It is probably best to stick to using queues or pipes for communication between processes rather than using the lower level synchronization primitives from the `threading` module.

#### Picklability

Ensure that the arguments to the methods of proxies are picklable.

#### Thread safety of proxies

Do not use a proxy object from more than one thread unless you protect it with a lock.

(There is never a problem with different processes using the *same* proxy.)

#### Joining zombie processes

On Unix when a process finishes but has not been joined it becomes a zombie. There should never be very many because each time a new process starts (or `active_children()` is called) all completed processes which have not yet been joined will be joined. Also calling a finished process's `Process.is_alive()` will join the process. Even so it is probably good practice to explicitly join all the processes that you start.

#### Better to inherit than pickle/unpickle

On Windows many types from `multiprocessing` need to be picklable so that child processes can use them. However, one should generally avoid sending shared objects to other processes using pipes or queues. Instead you should arrange the program so that a process which needs access to a shared resource created elsewhere can inherit it from an ancestor process.

#### Avoid terminating processes

Using the `Process.terminate()` method to stop a process is liable to cause any shared resources (such as locks, semaphores, pipes and queues) currently being used by the process to become broken or unavailable to other processes.

Therefore it is probably best to only consider using `Process.terminate()` on processes which never use any shared resources.

## Joining processes that use queues

Bear in mind that a process that has put items in a queue will wait before terminating until all the buffered items are fed by the “feeder” thread to the underlying pipe. (The child process can call the `cancel_join_thread()` method of the queue to avoid this behaviour.)

This means that whenever you use a queue you need to make sure that all items which have been put on the queue will eventually be removed before the process is joined. Otherwise you cannot be sure that processes which have put items on the queue will terminate. Remember also that non-daemonic processes will be automatically be joined.

An example which will deadlock is the following:

```
from multiprocessing import Process, Queue

def f(q):
    q.put('X' * 1000000)

if __name__ == '__main__':
    queue = Queue()
    p = Process(target=f, args=(queue,))
    p.start()
    p.join()                # this deadlocks
    obj = queue.get()
```

A fix here would be to swap the last two lines round (or simply remove the `p.join()` line).

## Explicitly pass resources to child processes

On Unix a child process can make use of a shared resource created in a parent process using a global resource. However, it is better to pass the object as an argument to the constructor for the child process.

Apart from making the code (potentially) compatible with Windows this also ensures that as long as the child process is still alive the object will not be garbage collected in the parent process. This might be important if some resource is freed when the object is garbage collected in the parent process.

So for instance

```
from multiprocessing import Process, Lock

def f():
    ... do something using "lock" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f).start()
```

should be rewritten as

```
from multiprocessing import Process, Lock

def f(l):
    ... do something using "l" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f, args=(lock,)).start()
```

Beware of replacing `sys.stdin` with a “file like object”

`multiprocessing` originally unconditionally called:

```
os.close(sys.stdin.fileno())
```

in the `multiprocessing.Process._bootstrap()` method — this resulted in issues with processes-in-processes. This has been changed to:

```
sys.stdin.close()
sys.stdin = open(os.devnull)
```

Which solves the fundamental issue of processes colliding with each other resulting in a bad file descriptor error, but introduces a potential danger to applications which replace `sys.stdin()` with a “file-like object” with output buffering. This danger is that if multiple processes call `close()` on this file-like object, it could result in the same data being flushed to the object multiple times, resulting in corruption.

If you write a file-like object and implement your own caching, you can make it fork-safe by storing the pid whenever you append to the cache, and discarding the cache when the pid changes. For example:

```
@property
def cache(self):
    pid = os.getpid()
    if pid != self._pid:
        self._pid = pid
        self._cache = []
    return self._cache
```

For more information, see [issue 5155](#), [issue 5313](#) and [issue 5331](#)

## Windows

Since Windows lacks `os.fork()` it has a few extra restrictions:

More picklability

Ensure that all arguments to `Process.__init__()` are picklable. This means, in particular, that bound or unbound methods cannot be used directly as the `target` argument on Windows — just define a function and use that instead.

Also, if you subclass `Process` then make sure that instances will be picklable when the `Process.start()` method is called.

Global variables

Bear in mind that if code run in a child process tries to access a global variable, then the value it sees (if any) may not be the same as the value in the parent process at the time that `Process.start()` was called.

However, global variables which are just module level constants cause no problems.

Safe importing of main module

Make sure that the main module can be safely imported by a new Python interpreter without causing unintended side effects (such as starting a new process).

For example, under Windows running the following module would fail with a `RuntimeError`:

```
from multiprocessing import Process

def foo():
    print 'hello'
```

```
p = Process(target=foo)
p.start()
```

Instead one should protect the “entry point” of the program by using `if __name__ == '__main__':` as follows:

```
from multiprocessing import Process, freeze_support

def foo():
    print 'hello'

if __name__ == '__main__':
    freeze_support()
    p = Process(target=foo)
    p.start()
```

(The `freeze_support()` line can be omitted if the program will be run normally instead of frozen.)

This allows the newly spawned Python interpreter to safely import the module and then run the module’s `foo()` function.

Similar restrictions apply if a pool or manager is created in the main module.

## 16.6.4 Examples

Demonstration of how to create and use customized managers and proxies:

```
#
# This module shows how to use arbitrary callables with a subclass of
# 'BaseManager'.
#
# Copyright (c) 2006–2008, R Oudkerk
# All rights reserved.
#

from multiprocessing import freeze_support
from multiprocessing.managers import BaseManager, BaseProxy
import operator

##

class Foo(object):
    def f(self):
        print 'you called Foo.f()'
    def g(self):
        print 'you called Foo.g()'
    def _h(self):
        print 'you called Foo._h()'

# A simple generator function
def baz():
    for i in xrange(10):
        yield i*i

# Proxy type for generator objects
```

```
class GeneratorProxy(BaseProxy):
    _exposed_ = ('next', '__next__')
    def __iter__(self):
        return self
    def next(self):
        return self._callmethod('next')
    def __next__(self):
        return self._callmethod('__next__')

# Function to return the operator module
def get_operator_module():
    return operator

##

class MyManager(BaseManager):
    pass

# register the Foo class; make 'f()' and 'g()' accessible via proxy
MyManager.register('Foo1', Foo)

# register the Foo class; make 'g()' and '_h()' accessible via proxy
MyManager.register('Foo2', Foo, exposed=('g', '_h'))

# register the generator function baz; use 'GeneratorProxy' to make proxies
MyManager.register('baz', baz, proxytype=GeneratorProxy)

# register get_operator_module(); make public functions accessible via proxy
MyManager.register('operator', get_operator_module)

##

def test():
    manager = MyManager()
    manager.start()

    print '-' * 20

    f1 = manager.Foo1()
    f1.f()
    f1.g()
    assert not hasattr(f1, '_h')
    assert sorted(f1._exposed_) == sorted(['f', 'g'])

    print '-' * 20

    f2 = manager.Foo2()
    f2.g()
    f2._h()
    assert not hasattr(f2, 'f')
    assert sorted(f2._exposed_) == sorted(['g', '_h'])

    print '-' * 20
```

```

it = manager.baz()
for i in it:
    print '<%d>' % i,
print

print '-' * 20

op = manager.operator()
print 'op.add(23, 45) =', op.add(23, 45)
print 'op.pow(2, 94) =', op.pow(2, 94)
print 'op.getslice(range(10), 2, 6) =', op.getslice(range(10), 2, 6)
print 'op.repeat(range(5), 3) =', op.repeat(range(5), 3)
print 'op._exposed_ =', op._exposed_

##

if __name__ == '__main__':
    freeze_support()
    test()

```

Using Pool:

```

#
# A test of 'multiprocessing.Pool' class
#
# Copyright (c) 2006-2008, R Oudkerk
# All rights reserved.
#

import multiprocessing
import time
import random
import sys

#
# Functions used by test code
#

def calculate(func, args):
    result = func(*args)
    return '%s says that %s%s = %s' % (
        multiprocessing.current_process().name,
        func.__name__, args, result
    )

def calculatestar(args):
    return calculate(*args)

def mul(a, b):
    time.sleep(0.5*random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5*random.random())
    return a + b

```

```
def f(x):
    return 1.0 / (x-5.0)

def pow3(x):
    return x**3

def noop(x):
    pass

#
# Test code
#

def test():
    print 'cpu_count() = %d\n' % multiprocessing.cpu_count()

    #
    # Create pool
    #

    PROCESSES = 4
    print 'Creating pool with %d processes\n' % PROCESSES
    pool = multiprocessing.Pool(PROCESSES)
    print 'pool = %s' % pool
    print

    #
    # Tests
    #

    TASKS = [(mul, (i, 7)) for i in range(10)] + \
            [(plus, (i, 8)) for i in range(10)]

    results = [pool.apply_async(calculate, t) for t in TASKS]
    imap_it = pool.imap(calculatestar, TASKS)
    imap_unordered_it = pool.imap_unordered(calculatestar, TASKS)

    print 'Ordered results using pool.apply_async():'
    for r in results:
        print '\t', r.get()
    print

    print 'Ordered results using pool.imap():'
    for x in imap_it:
        print '\t', x
    print

    print 'Unordered results using pool.imap_unordered():'
    for x in imap_unordered_it:
        print '\t', x
    print

    print 'Ordered results using pool.map() --- will block till complete:'
```

```

for x in pool.map(calculatestar, TASKS):
    print '\t', x
print

#
# Simple benchmarks
#

N = 100000
print 'def pow3(x): return x**3'

t = time.time()
A = map(pow3, xrange(N))
print '\tmap(pow3, xrange(%d)):\n\t\t%s seconds' % \
      (N, time.time() - t)

t = time.time()
B = pool.map(pow3, xrange(N))
print '\tpool.map(pow3, xrange(%d)):\n\t\t%s seconds' % \
      (N, time.time() - t)

t = time.time()
C = list(pool.imap(pow3, xrange(N), chunksize=N//8))
print '\tlist(pool.imap(pow3, xrange(%d), chunksize=%d)):\n\t\t%s' \
      ' seconds' % (N, N//8, time.time() - t)

assert A == B == C, (len(A), len(B), len(C))
print

L = [None] * 1000000
print 'def noop(x): pass'
print 'L = [None] * 1000000'

t = time.time()
A = map(noop, L)
print '\tmap(noop, L):\n\t\t%s seconds' % \
      (time.time() - t)

t = time.time()
B = pool.map(noop, L)
print '\tpool.map(noop, L):\n\t\t%s seconds' % \
      (time.time() - t)

t = time.time()
C = list(pool.imap(noop, L, chunksize=len(L)//8))
print '\tlist(pool.imap(noop, L, chunksize=%d)):\n\t\t%s seconds' % \
      (len(L)//8, time.time() - t)

assert A == B == C, (len(A), len(B), len(C))
print

del A, B, C, L

#

```

```
# Test error handling
#

print 'Testing error handling:'

try:
    print pool.apply(f, (5,))
except ZeroDivisionError:
    print '\tGot ZeroDivisionError as expected from pool.apply()'
else:
    raise AssertionError('expected ZeroDivisionError')

try:
    print pool.map(f, range(10))
except ZeroDivisionError:
    print '\tGot ZeroDivisionError as expected from pool.map()'
else:
    raise AssertionError('expected ZeroDivisionError')

try:
    print list(pool.imap(f, range(10)))
except ZeroDivisionError:
    print '\tGot ZeroDivisionError as expected from list(pool.imap())'
else:
    raise AssertionError('expected ZeroDivisionError')

it = pool.imap(f, range(10))
for i in range(10):
    try:
        x = it.next()
    except ZeroDivisionError:
        if i == 5:
            pass
    except StopIteration:
        break
    else:
        if i == 5:
            raise AssertionError('expected ZeroDivisionError')

assert i == 9
print '\tGot ZeroDivisionError as expected from IMapIterator.next()'
print

#
# Testing timeouts
#

print 'Testing ApplyResult.get() with timeout:',
res = pool.apply_async(calculate, TASKS[0])
while 1:
    sys.stdout.flush()
    try:
        sys.stdout.write('\n\t%s' % res.get(0.02))
        break
```

```

        except multiprocessing.TimeoutError:
            sys.stdout.write('.')
    print
    print

    print 'Testing IMapIterator.next() with timeout:',
    it = pool.imap(calculatestar, TASKS)
    while 1:
        sys.stdout.flush()
        try:
            sys.stdout.write('\n\t%s' % it.next(0.02))
        except StopIteration:
            break
        except multiprocessing.TimeoutError:
            sys.stdout.write('.')
    print
    print

    #
    # Testing callback
    #

    print 'Testing callback:'

    A = []
    B = [56, 0, 1, 8, 27, 64, 125, 216, 343, 512, 729]

    r = pool.apply_async(mul, (7, 8), callback=A.append)
    r.wait()

    r = pool.map_async(pow3, range(10), callback=A.extend)
    r.wait()

    if A == B:
        print '\tcallbacks succeeded\n'
    else:
        print '\t*** callbacks failed\n\t\t%s != %s\n' % (A, B)

    #
    # Check there are no outstanding tasks
    #

    assert not pool._cache, 'cache = %r' % pool._cache

    #
    # Check close() methods
    #

    print 'Testing close():'

    for worker in pool._pool:
        assert worker.is_alive()

    result = pool.apply_async(time.sleep, [0.5])

```

```
pool.close()
pool.join()

assert result.get() is None

for worker in pool._pool:
    assert not worker.is_alive()

print '\tclose() succeeded\n'

#
# Check terminate() method
#

print 'Testing terminate():'

pool = multiprocessing.Pool(2)
DELTA = 0.1
ignore = pool.apply(pow3, [2])
results = [pool.apply_async(time.sleep, [DELTA]) for i in range(100)]
pool.terminate()
pool.join()

for worker in pool._pool:
    assert not worker.is_alive()

print '\tterminate() succeeded\n'

#
# Check garbage collection
#

print 'Testing garbage collection:'

pool = multiprocessing.Pool(2)
DELTA = 0.1
processes = pool._pool
ignore = pool.apply(pow3, [2])
results = [pool.apply_async(time.sleep, [DELTA]) for i in range(100)]

results = pool = None

time.sleep(DELTA * 2)

for worker in processes:
    assert not worker.is_alive()

print '\tgarbage collection succeeded\n'

if __name__ == '__main__':
    multiprocessing.freeze_support()

    assert len(sys.argv) in (1, 2)
```

```

if len(sys.argv) == 1 or sys.argv[1] == 'processes':
    print ' Using processes '.center(79, '-')
elif sys.argv[1] == 'threads':
    print ' Using threads '.center(79, '-')
    import multiprocessing.dummy as multiprocessing
else:
    print 'Usage:\n\t%s [processes | threads]' % sys.argv[0]
    raise SystemExit(2)

test()

```

Synchronization types like locks, conditions and queues:

```

#
# A test file for the 'multiprocessing' package
#
# Copyright (c) 2006-2008, R Oudkerk
# All rights reserved.
#

import time, sys, random
from Queue import Empty

import multiprocessing                # may get overwritten

#### TEST_VALUE

def value_func(running, mutex):
    random.seed()
    time.sleep(random.random()*4)

    mutex.acquire()
    print '\n\t\t\t' + str(multiprocessing.current_process()) + ' has finished'
    running.value -= 1
    mutex.release()

def test_value():
    TASKS = 10
    running = multiprocessing.Value('i', TASKS)
    mutex = multiprocessing.Lock()

    for i in range(TASKS):
        p = multiprocessing.Process(target=value_func, args=(running, mutex))
        p.start()

    while running.value > 0:
        time.sleep(0.08)
        mutex.acquire()
        print running.value,
        sys.stdout.flush()
        mutex.release()

print

```

```
    print 'No more running processes'
```

```
##### TEST_QUEUE
```

```
def queue_func(queue):
    for i in range(30):
        time.sleep(0.5 * random.random())
        queue.put(i*i)
    queue.put('STOP')
```

```
def test_queue():
    q = multiprocessing.Queue()

    p = multiprocessing.Process(target=queue_func, args=(q,))
    p.start()

    o = None
    while o != 'STOP':
        try:
            o = q.get(timeout=0.3)
            print o,
            sys.stdout.flush()
        except Empty:
            print 'TIMEOUT'

    print
```

```
##### TEST_CONDITION
```

```
def condition_func(cond):
    cond.acquire()
    print '\t' + str(cond)
    time.sleep(2)
    print '\tchild is notifying'
    print '\t' + str(cond)
    cond.notify()
    cond.release()
```

```
def test_condition():
    cond = multiprocessing.Condition()

    p = multiprocessing.Process(target=condition_func, args=(cond,))
    print cond

    cond.acquire()
    print cond
    cond.acquire()
    print cond

    p.start()

    print 'main is waiting'
```

```

cond.wait()
print 'main has woken up'

print cond
cond.release()
print cond
cond.release()

p.join()
print cond

#### TEST_SEMAPHORE

def semaphore_func(sema, mutex, running):
    sema.acquire()

    mutex.acquire()
    running.value += 1
    print running.value, 'tasks are running'
    mutex.release()

    random.seed()
    time.sleep(random.random()*2)

    mutex.acquire()
    running.value -= 1
    print '%s has finished' % multiprocessing.current_process()
    mutex.release()

    sema.release()

def test_semaphore():
    sema = multiprocessing.Semaphore(3)
    mutex = multiprocessing.RLock()
    running = multiprocessing.Value('i', 0)

    processes = [
        multiprocessing.Process(target=semaphore_func,
                                args=(sema, mutex, running))
        for i in range(10)
    ]

    for p in processes:
        p.start()

    for p in processes:
        p.join()

#### TEST_JOIN_TIMEOUT

def join_timeout_func():
    print '\tchild sleeping'

```

```
    time.sleep(5.5)
    print '\n\tchild terminating'

def test_join_timeout():
    p = multiprocessing.Process(target=join_timeout_func)
    p.start()

    print 'waiting for process to finish'

    while 1:
        p.join(timeout=1)
        if not p.is_alive():
            break
        print '.',
        sys.stdout.flush()

#### TEST_EVENT

def event_func(event):
    print '\t%r is waiting' % multiprocessing.current_process()
    event.wait()
    print '\t%r has woken up' % multiprocessing.current_process()

def test_event():
    event = multiprocessing.Event()

    processes = [multiprocessing.Process(target=event_func, args=(event,))
                 for i in range(5)]

    for p in processes:
        p.start()

    print 'main is sleeping'
    time.sleep(2)

    print 'main is setting event'
    event.set()

    for p in processes:
        p.join()

#### TEST_SHAREDVALUES

def sharedvalues_func(values, arrays, shared_values, shared_arrays):
    for i in range(len(values)):
        v = values[i][1]
        sv = shared_values[i].value
        assert v == sv

    for i in range(len(values)):
        a = arrays[i][1]
        sa = list(shared_arrays[i][:])
```

```

    assert a == sa

    print 'Tests passed'

def test_sharedvalues():
    values = [
        ('i', 10),
        ('h', -2),
        ('d', 1.25)
    ]
    arrays = [
        ('i', range(100)),
        ('d', [0.25 * i for i in range(100)]),
        ('H', range(1000))
    ]

    shared_values = [multiprocessing.Value(id, v) for id, v in values]
    shared_arrays = [multiprocessing.Array(id, a) for id, a in arrays]

    p = multiprocessing.Process(
        target=sharedvalues_func,
        args=(values, arrays, shared_values, shared_arrays)
    )
    p.start()
    p.join()

    assert p.exitcode == 0

####

def test(namespace=multiprocessing):
    global multiprocessing

    multiprocessing = namespace

    for func in [ test_value, test_queue, test_condition,
                 test_semaphore, test_join_timeout, test_event,
                 test_sharedvalues ]:

        print '\n\t##### %s\n' % func.__name__
        func()

    ignore = multiprocessing.active_children()           # cleanup any old processes
    if hasattr(multiprocessing, '_debug_info'):
        info = multiprocessing._debug_info()
        if info:
            print info
            raise ValueError('there should be no positive refcounts left')

if __name__ == '__main__':
    multiprocessing.freeze_support()

```

```
assert len(sys.argv) in (1, 2)

if len(sys.argv) == 1 or sys.argv[1] == 'processes':
    print ' Using processes '.center(79, '-')
    namespace = multiprocessing
elif sys.argv[1] == 'manager':
    print ' Using processes and a manager '.center(79, '-')
    namespace = multiprocessing.Manager()
    namespace.Process = multiprocessing.Process
    namespace.current_process = multiprocessing.current_process
    namespace.active_children = multiprocessing.active_children
elif sys.argv[1] == 'threads':
    print ' Using threads '.center(79, '-')
    import multiprocessing.dummy as namespace
else:
    print 'Usage:\n\t%s [processes | manager | threads]' % sys.argv[0]
    raise SystemExit(2)

test(namespace)
```

An example showing how to use queues to feed tasks to a collection of worker processes and collect the results:

```
#
# Simple example which uses a pool of workers to carry out some tasks.
#
# Notice that the results will probably not come out of the output
# queue in the same in the same order as the corresponding tasks were
# put on the input queue. If it is important to get the results back
# in the original order then consider using 'Pool.map()' or
# 'Pool.imap()' (which will save on the amount of code needed anyway).
#
# Copyright (c) 2006-2008, R Oudkerk
# All rights reserved.
#

import time
import random

from multiprocessing import Process, Queue, current_process, freeze_support

#
# Function run by worker processes
#

def worker(input, output):
    for func, args in iter(input.get, 'STOP'):
        result = calculate(func, args)
        output.put(result)

#
# Function used to calculate result
#

def calculate(func, args):
    result = func(*args)
```

```

    return '%s says that %s%s = %s' % \
        (current_process().name, func.__name__, args, result)

#
# Functions referenced by tasks
#

def mul(a, b):
    time.sleep(0.5*random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5*random.random())
    return a + b

#
#
#

def test():
    NUMBER_OF_PROCESSES = 4
    TASKS1 = [(mul, (i, 7)) for i in range(20)]
    TASKS2 = [(plus, (i, 8)) for i in range(10)]

    # Create queues
    task_queue = Queue()
    done_queue = Queue()

    # Submit tasks
    for task in TASKS1:
        task_queue.put(task)

    # Start worker processes
    for i in range(NUMBER_OF_PROCESSES):
        Process(target=worker, args=(task_queue, done_queue)).start()

    # Get and print results
    print 'Unordered results:'
    for i in range(len(TASKS1)):
        print '\t', done_queue.get()

    # Add more tasks using 'put()'
    for task in TASKS2:
        task_queue.put(task)

    # Get and print some more results
    for i in range(len(TASKS2)):
        print '\t', done_queue.get()

    # Tell child processes to stop
    for i in range(NUMBER_OF_PROCESSES):
        task_queue.put('STOP')

```

```
if __name__ == '__main__':
    freeze_support()
    test()
```

An example of how a pool of worker processes can each run a `SimpleHTTPServer.HTTPServer` instance while sharing a single listening socket.

```
#
# Example where a pool of http servers share a single listening socket
#
# On Windows this module depends on the ability to pickle a socket
# object so that the worker processes can inherit a copy of the server
# object. (We import 'multiprocessing.reduction' to enable this pickling.)
#
# Not sure if we should synchronize access to 'socket.accept()' method by
# using a process-shared lock -- does not seem to be necessary.
#
# Copyright (c) 2006-2008, R Oudkerk
# All rights reserved.
#

import os
import sys

from multiprocessing import Process, current_process, freeze_support
from BaseHTTPServer import HTTPServer
from SimpleHTTPServer import SimpleHTTPRequestHandler

if sys.platform == 'win32':
    import multiprocessing.reduction # make sockets pickable/inheritable

def note(format, *args):
    sys.stderr.write(' [%s]\t%s\n' % (current_process().name, format%args))

class RequestHandler(SimpleHTTPRequestHandler):
    # we override log_message() to show which process is handling the request
    def log_message(self, format, *args):
        note(format, *args)

def serve_forever(server):
    note('starting server')
    try:
        server.serve_forever()
    except KeyboardInterrupt:
        pass

def runpool(address, number_of_processes):
    # create a single server object -- children will each inherit a copy
    server = HTTPServer(address, RequestHandler)

    # create child processes to act as workers
    for i in range(number_of_processes-1):
```

```

    Process(target=serve_forever, args=(server,)).start()

    # main process also acts as a worker
    serve_forever(server)

def test():
    DIR = os.path.join(os.path.dirname(__file__), '..')
    ADDRESS = ('localhost', 8000)
    NUMBER_OF_PROCESSES = 4

    print 'Serving at http://%s:%d using %d worker processes' % \
        (ADDRESS[0], ADDRESS[1], NUMBER_OF_PROCESSES)
    print 'To exit press Ctrl-' + ['C', 'Break'][sys.platform=='win32']

    os.chdir(DIR)
    runpool(ADDRESS, NUMBER_OF_PROCESSES)

if __name__ == '__main__':
    freeze_support()
    test()

```

Some simple benchmarks comparing multiprocessing with threading:

```

#
# Simple benchmarks for the multiprocessing package
#
# Copyright (c) 2006-2008, R Oudkerk
# All rights reserved.
#

import time, sys, multiprocessing, threading, Queue, gc

if sys.platform == 'win32':
    _timer = time.clock
else:
    _timer = time.time

delta = 1

#### TEST_QUEUESPEED

def queuespeed_func(q, c, iterations):
    a = '0' * 256
    c.acquire()
    c.notify()
    c.release()

    for i in xrange(iterations):
        q.put(a)

    q.put('STOP')

```

```
def test_queuespeed(Process, q, c):
    elapsed = 0
    iterations = 1

    while elapsed < delta:
        iterations *= 2

        p = Process(target=queuespeed_func, args=(q, c, iterations))
        c.acquire()
        p.start()
        c.wait()
        c.release()

        result = None
        t = _timer()

        while result != 'STOP':
            result = q.get()

        elapsed = _timer() - t

        p.join()

    print iterations, 'objects passed through the queue in', elapsed, 'seconds'
    print 'average number/sec:', iterations/elapsed

#### TEST_PIPESPEED

def pipe_func(c, cond, iterations):
    a = '0' * 256
    cond.acquire()
    cond.notify()
    cond.release()

    for i in xrange(iterations):
        c.send(a)

    c.send('STOP')

def test_pipespeed():
    c, d = multiprocessing.Pipe()
    cond = multiprocessing.Condition()
    elapsed = 0
    iterations = 1

    while elapsed < delta:
        iterations *= 2

        p = multiprocessing.Process(target=pipe_func,
                                    args=(d, cond, iterations))

        cond.acquire()
        p.start()
        cond.wait()
```

```

    cond.release()

    result = None
    t = _timer()

    while result != 'STOP':
        result = c.recv()

    elapsed = _timer() - t
    p.join()

    print iterations, 'objects passed through connection in', elapsed, 'seconds'
    print 'average number/sec:', iterations/elapsed

#### TEST_SEQSPEED

def test_seqspeak(seq):
    elapsed = 0
    iterations = 1

    while elapsed < delta:
        iterations *= 2

    t = _timer()

    for i in xrange(iterations):
        a = seq[5]

    elapsed = _timer()-t

    print iterations, 'iterations in', elapsed, 'seconds'
    print 'average number/sec:', iterations/elapsed

#### TEST_LOCK

def test_lockspeed(l):
    elapsed = 0
    iterations = 1

    while elapsed < delta:
        iterations *= 2

    t = _timer()

    for i in xrange(iterations):
        l.acquire()
        l.release()

    elapsed = _timer()-t

    print iterations, 'iterations in', elapsed, 'seconds'
    print 'average number/sec:', iterations/elapsed

```

```
#### TEST_CONDITION

def conditionspeed_func(c, N):
    c.acquire()
    c.notify()

    for i in xrange(N):
        c.wait()
        c.notify()

    c.release()

def test_conditionspeed(Process, c):
    elapsed = 0
    iterations = 1

    while elapsed < delta:
        iterations *= 2

        c.acquire()
        p = Process(target=conditionspeed_func, args=(c, iterations))
        p.start()

        c.wait()

        t = _timer()

        for i in xrange(iterations):
            c.notify()
            c.wait()

        elapsed = _timer()-t

        c.release()
        p.join()

    print iterations * 2, 'waits in', elapsed, 'seconds'
    print 'average number/sec:', iterations * 2 / elapsed

####

def test():
    manager = multiprocessing.Manager()

    gc.disable()

    print '\n\t##### testing Queue.Queue\n'
    test_queuespeed(threading.Thread, Queue.Queue(),
                    threading.Condition())
    print '\n\t##### testing multiprocessing.Queue\n'
    test_queuespeed(multiprocessing.Process, multiprocessing.Queue(),
                    multiprocessing.Condition())
```

```

print '\n\t##### testing Queue managed by server process\n'
test_queuespeed(multiprocessing.Process, manager.Queue(),
                 manager.Condition())
print '\n\t##### testing multiprocessing.Pipe\n'
test_pipespeed()

print

print '\n\t##### testing list\n'
test_seqspeek(range(10))
print '\n\t##### testing list managed by server process\n'
test_seqspeek(manager.list(range(10)))
print '\n\t##### testing Array("i", ..., lock=False)\n'
test_seqspeek(multiprocessing.Array('i', range(10), lock=False))
print '\n\t##### testing Array("i", ..., lock=True)\n'
test_seqspeek(multiprocessing.Array('i', range(10), lock=True))

print

print '\n\t##### testing threading.Lock\n'
test_lockspeed(threading.Lock())
print '\n\t##### testing threading.RLock\n'
test_lockspeed(threading.RLock())
print '\n\t##### testing multiprocessing.Lock\n'
test_lockspeed(multiprocessing.Lock())
print '\n\t##### testing multiprocessing.RLock\n'
test_lockspeed(multiprocessing.RLock())
print '\n\t##### testing lock managed by server process\n'
test_lockspeed(manager.Lock())
print '\n\t##### testing rlock managed by server process\n'
test_lockspeed(manager.RLock())

print

print '\n\t##### testing threading.Condition\n'
test_conditionspeed(threading.Thread, threading.Condition())
print '\n\t##### testing multiprocessing.Condition\n'
test_conditionspeed(multiprocessing.Process, multiprocessing.Condition())
print '\n\t##### testing condition managed by a server process\n'
test_conditionspeed(multiprocessing.Process, manager.Condition())

gc.enable()

if __name__ == '__main__':
    multiprocessing.freeze_support()
    test()

```

## 16.7 mmap — Memory-mapped file support

Memory-mapped file objects behave like both strings and like file objects. Unlike normal string objects, however, these are mutable. You can use mmap objects in most places where strings are expected; for example, you can use the `re` module to search through a memory-mapped file. Since they're mutable, you can change a single character by

doing `obj[index] = 'a'`, or change a substring by assigning to a slice: `obj[i1:i2] = '...'`. You can also read and write data starting at the current file position, and `seek()` through the file to different positions.

A memory-mapped file is created by the `mmap` constructor, which is different on Unix and on Windows. In either case you must provide a file descriptor for a file opened for update. If you wish to map an existing Python file object, use its `fileno()` method to obtain the correct value for the `fileno` parameter. Otherwise, you can open the file using the `os.open()` function, which returns a file descriptor directly (the file still needs to be closed when done).

---

**Note:** If you want to create a memory-mapping for a writable, buffered file, you should `flush()` the file first. This is necessary to ensure that local modifications to the buffers are actually available to the mapping.

---

For both the Unix and Windows versions of the constructor, `access` may be specified as an optional keyword parameter. `access` accepts one of three values: `ACCESS_READ`, `ACCESS_WRITE`, or `ACCESS_COPY` to specify read-only, write-through or copy-on-write memory respectively. `access` can be used on both Unix and Windows. If `access` is not specified, Windows `mmap` returns a write-through mapping. The initial memory values for all three access types are taken from the specified file. Assignment to an `ACCESS_READ` memory map raises a `TypeError` exception. Assignment to an `ACCESS_WRITE` memory map affects both memory and the underlying file. Assignment to an `ACCESS_COPY` memory map affects memory but does not update the underlying file. Changed in version 2.5: To map anonymous memory, -1 should be passed as the `fileno` along with the `length`. Changed in version 2.6: `mmap.mmap` has formerly been a factory function creating `mmap` objects. Now `mmap.mmap` is the class itself.

**class** `mmap.mmap` (*fileno*, *length*[, *tagname*[, *access*[, *offset*]]])

**(Windows version)** Maps *length* bytes from the file specified by the file handle *fileno*, and creates a `mmap` object. If *length* is larger than the current size of the file, the file is extended to contain *length* bytes. If *length* is 0, the maximum length of the map is the current size of the file, except that if the file is empty Windows raises an exception (you cannot create an empty mapping on Windows).

*tagname*, if specified and not `None`, is a string giving a tag name for the mapping. Windows allows you to have many different mappings against the same file. If you specify the name of an existing tag, that tag is opened, otherwise a new tag of this name is created. If this parameter is omitted or `None`, the mapping is created without a name. Avoiding the use of the tag parameter will assist in keeping your code portable between Unix and Windows.

*offset* may be specified as a non-negative integer offset. `mmap` references will be relative to the offset from the beginning of the file. *offset* defaults to 0. *offset* must be a multiple of the `ALLOCATIONGRANULARITY`.

**class** `mmap.mmap` (*fileno*, *length*[, *flags*[, *prot*[, *access*[, *offset*]]])

**(Unix version)** Maps *length* bytes from the file specified by the file descriptor *fileno*, and returns a `mmap` object. If *length* is 0, the maximum length of the map will be the current size of the file when `mmap` is called.

*flags* specifies the nature of the mapping. `MAP_PRIVATE` creates a private copy-on-write mapping, so changes to the contents of the `mmap` object will be private to this process, and `MAP_SHARED` creates a mapping that's shared with all other processes mapping the same areas of the file. The default value is `MAP_SHARED`.

*prot*, if specified, gives the desired memory protection; the two most useful values are `PROT_READ` and `PROT_WRITE`, to specify that the pages may be read or written. *prot* defaults to `PROT_READ | PROT_WRITE`.

*access* may be specified in lieu of *flags* and *prot* as an optional keyword parameter. It is an error to specify both *flags*, *prot* and *access*. See the description of `access` above for information on how to use this parameter.

*offset* may be specified as a non-negative integer offset. `mmap` references will be relative to the offset from the beginning of the file. *offset* defaults to 0. *offset* must be a multiple of the `PAGESIZE` or `ALLOCATIONGRANULARITY`.

To ensure validity of the created memory mapping the file specified by the descriptor *fileno* is internally automatically synchronized with physical backing store on Mac OS X and OpenVMS.

This example shows a simple way of using `mmap`:

```

import mmap

# write a simple example file
with open("hello.txt", "wb") as f:
    f.write("Hello Python!\n")

with open("hello.txt", "r+b") as f:
    # memory-map the file, size 0 means whole file
    map = mmap.mmap(f.fileno(), 0)
    # read content via standard file methods
    print map.readline() # prints "Hello Python!"
    # read content via slice notation
    print map[:5] # prints "Hello"
    # update content using slice notation;
    # note that new content must have same size
    map[6:] = " world!\n"
    # ... and read again using standard file methods
    map.seek(0)
    print map.readline() # prints "Hello world!"
    # close the map
    map.close()

```

The next example demonstrates how to create an anonymous map and exchange data between the parent and child processes:

```

import mmap
import os

map = mmap.mmap(-1, 13)
map.write("Hello world!")

pid = os.fork()

if pid == 0: # In a child process
    map.seek(0)
    print map.readline()

    map.close()

```

Memory-mapped file objects support the following methods:

`mmap.close()`

Close the file. Subsequent calls to other methods of the object will result in an exception being raised.

`mmap.find(string[, start[, end]])`

Returns the lowest index in the object where the substring *string* is found, such that *string* is contained in the range *[start, end]*. Optional arguments *start* and *end* are interpreted as in slice notation. Returns `-1` on failure.

`mmap.flush([offset, size])`

Flushes changes made to the in-memory copy of a file back to disk. Without use of this call there is no guarantee that changes are written back before the object is destroyed. If *offset* and *size* are specified, only changes to the given range of bytes will be flushed to disk; otherwise, the whole extent of the mapping is flushed.

**(Windows version)** A nonzero value returned indicates success; zero indicates failure.

**(Unix version)** A zero value is returned to indicate success. An exception is raised when the call failed.

`mmap.move(dest, src, count)`

Copy the *count* bytes starting at offset *src* to the destination index *dest*. If the mmap was created with `ACCESS_READ`, then calls to move will raise a `TypeError` exception.

`mmap.read(num)`

Return a string containing up to *num* bytes starting from the current file position; the file position is updated to point after the bytes that were returned.

`mmap.read_byte()`

Returns a string of length 1 containing the character at the current file position, and advances the file position by 1.

`mmap.readline()`

Returns a single line, starting at the current file position and up to the next newline.

`mmap.resize(newsize)`

Resizes the map and the underlying file, if any. If the mmap was created with `ACCESS_READ` or `ACCESS_COPY`, resizing the map will raise a `TypeError` exception.

`mmap.rfind(string[, start[, end]])`

Returns the highest index in the object where the substring *string* is found, such that *string* is contained in the range *[start, end]*. Optional arguments *start* and *end* are interpreted as in slice notation. Returns `-1` on failure.

`mmap.seek(pos[, whence])`

Set the file's current position. *whence* argument is optional and defaults to `os.SEEK_SET` or 0 (absolute file positioning); other values are `os.SEEK_CUR` or 1 (seek relative to the current position) and `os.SEEK_END` or 2 (seek relative to the file's end).

`mmap.size()`

Return the length of the file, which can be larger than the size of the memory-mapped area.

`mmap.tell()`

Returns the current position of the file pointer.

`mmap.write(string)`

Write the bytes in *string* into memory at the current position of the file pointer; the file position is updated to point after the bytes that were written. If the mmap was created with `ACCESS_READ`, then writing to it will raise a `TypeError` exception.

`mmap.write_byte(byte)`

Write the single-character string *byte* into memory at the current position of the file pointer; the file position is advanced by 1. If the mmap was created with `ACCESS_READ`, then writing to it will raise a `TypeError` exception.

## 16.8 readline — GNU readline interface

*Platforms:* Unix

The `readline` module defines a number of functions to facilitate completion and reading/writing of history files from the Python interpreter. This module can be used directly or via the `rlcompleter` module. Settings made using this module affect the behaviour of both the interpreter's interactive prompt and the prompts offered by the `raw_input()` and `input()` built-in functions.

---

**Note:** On MacOS X the `readline` module can be implemented using the `libedit` library instead of GNU `readline`.

The configuration file for `libedit` is different from that of GNU `readline`. If you programmatically load configuration strings you can check for the text “libedit” in `readline.__doc__` to differentiate between GNU `readline` and `libedit`.

The `readline` module defines the following functions:

- `readline.parse_and_bind(string)`  
Parse and execute single line of a readline init file.
- `readline.get_line_buffer()`  
Return the current contents of the line buffer.
- `readline.insert_text(string)`  
Insert text into the command line.
- `readline.read_init_file([filename])`  
Parse a readline initialization file. The default filename is the last filename used.
- `readline.read_history_file([filename])`  
Load a readline history file. The default filename is `~/.history`.
- `readline.write_history_file([filename])`  
Save a readline history file. The default filename is `~/.history`.
- `readline.clear_history()`  
Clear the current history. (Note: this function is not available if the installed version of GNU `readline` doesn't support it.) New in version 2.4.
- `readline.get_history_length()`  
Return the desired length of the history file. Negative values imply unlimited history file size.
- `readline.set_history_length(length)`  
Set the number of lines to save in the history file. `write_history_file()` uses this value to truncate the history file when saving. Negative values imply unlimited history file size.
- `readline.get_current_history_length()`  
Return the number of lines currently in the history. (This is different from `get_history_length()`, which returns the maximum number of lines that will be written to a history file.) New in version 2.3.
- `readline.get_history_item(index)`  
Return the current contents of history item at `index`. New in version 2.3.
- `readline.remove_history_item(pos)`  
Remove history item specified by its position from the history. New in version 2.4.
- `readline.replace_history_item(pos, line)`  
Replace history item specified by its position with the given line. New in version 2.4.
- `readline.redisplay()`  
Change what's displayed on the screen to reflect the current contents of the line buffer. New in version 2.3.
- `readline.set_startup_hook([function])`  
Set or remove the `startup_hook` function. If `function` is specified, it will be used as the new `startup_hook` function; if omitted or `None`, any hook function already installed is removed. The `startup_hook` function is called with no arguments just before `readline` prints the first prompt.
- `readline.set_pre_input_hook([function])`  
Set or remove the `pre_input_hook` function. If `function` is specified, it will be used as the new `pre_input_hook` function; if omitted or `None`, any hook function already installed is removed. The `pre_input_hook` function is called with no arguments after the first prompt has been printed and just before `readline` starts reading input characters.

`readline.set_completer([function])`  
Set or remove the completer function. If *function* is specified, it will be used as the new completer function; if omitted or `None`, any completer function already installed is removed. The completer function is called as `function(text, state)`, for *state* in 0, 1, 2, ..., until it returns a non-string value. It should return the next possible completion starting with *text*.

`readline.get_completer()`  
Get the completer function, or `None` if no completer function has been set. New in version 2.3.

`readline.get_completion_type()`  
Get the type of completion being attempted. New in version 2.6.

`readline.get_begidx()`  
Get the beginning index of the readline tab-completion scope.

`readline.get_endidx()`  
Get the ending index of the readline tab-completion scope.

`readline.set_completer_delims(string)`  
Set the readline word delimiters for tab-completion.

`readline.get_completer_delims()`  
Get the readline word delimiters for tab-completion.

`readline.set_completion_display_matches_hook([function])`  
Set or remove the completion display function. If *function* is specified, it will be used as the new completion display function; if omitted or `None`, any completion display function already installed is removed. The completion display function is called as `function(substitution, [matches], longest_match_length)` once each time matches need to be displayed. New in version 2.6.

`readline.add_history(line)`  
Append a line to the history buffer, as if it was the last line typed.

### See Also:

**Module `rlcompleter`** Completion of Python identifiers at the interactive prompt.

## 16.8.1 Example

The following example demonstrates how to use the `readline` module's history reading and writing functions to automatically load and save a history file named `.pyhist` from the user's home directory. The code below would normally be executed automatically during interactive sessions from the user's

PYTHONSTARTUP file.

```
import os
import readline
histfile = os.path.join(os.path.expanduser("~"), ".pyhist")
try:
    readline.read_history_file(histfile)
except IOError:
    pass
import atexit
atexit.register(readline.write_history_file, histfile)
del os, histfile
```

The following example extends the `code.InteractiveConsole` class to support history save/restore.

```
import code
import readline
```

```

import atexit
import os

class HistoryConsole(code.InteractiveConsole):
    def __init__(self, locals=None, filename="<console>",
                 histfile=os.path.expanduser("~/console-history")):
        code.InteractiveConsole.__init__(self, locals, filename)
        self.init_history(histfile)

    def init_history(self, histfile):
        readline.parse_and_bind("tab: complete")
        if hasattr(readline, "read_history_file"):
            try:
                readline.read_history_file(histfile)
            except IOError:
                pass
        atexit.register(self.save_history, histfile)

    def save_history(self, histfile):
        readline.write_history_file(histfile)

```

## 16.9 rlcompleter — Completion function for GNU readline

Source code: [Lib/rlcompleter.py](#)

The `rlcompleter` module defines a completion function suitable for the `readline` module by completing valid Python identifiers and keywords.

When this module is imported on a Unix platform with the `readline` module available, an instance of the `Completer` class is automatically created and its `complete()` method is set as the `readline` completer.

Example:

```

>>> import rlcompleter
>>> import readline
>>> readline.parse_and_bind("tab: complete")
>>> readline. <TAB PRESSED>
readline.__doc__      readline.get_line_buffer(  readline.read_init_file(
readline.__file__    readline.insert_text(      readline.set_completer(
readline.__name__    readline.parse_and_bind(
>>> readline.

```

The `rlcompleter` module is designed for use with Python's interactive mode. A user can add the following lines to his or her initialization file (identified by the `PYTHONSTARTUP` environment variable) to get automatic Tab completion:

```

try:
    import readline
except ImportError:
    print "Module readline not available."
else:
    import rlcompleter
    readline.parse_and_bind("tab: complete")

```

On platforms without `readline`, the `Completer` class defined by this module can still be used for custom purposes.

## 16.9.1 Completer Objects

Completer objects have the following method:

`Completer.complete` (*text*, *state*)

Return the *state* completion for *text*.

If called for *text* that doesn't include a period character ( `' . '` ), it will complete from names currently defined in `__main__`, `__builtin__` and keywords (as defined by the `keyword` module).

If called for a dotted name, it will try to evaluate anything without obvious side-effects (functions will not be evaluated, but it can generate calls to `__getattr__()` up to the last part, and find matches for the rest via the `dir()` function. Any exception raised during the evaluation of the expression is caught, silenced and `None` is returned.

# INTERPROCESS COMMUNICATION AND NETWORKING

The modules described in this chapter provide mechanisms for different processes to communicate.

Some modules only work for two processes that are on the same machine, e.g. `signal` and `subprocess`. Other modules support networking protocols that two or more processes can use to communicate across machines.

The list of modules described in this chapter is:

## 17.1 `subprocess` — Subprocess management

New in version 2.4. The `subprocess` module allows you to spawn new processes, connect to their input/output/error pipes, and obtain their return codes. This module intends to replace several other, older modules and functions, such as:

```
os.system
os.spawn*
os.popen*
popen2.*
commands.*
```

Information about how the `subprocess` module can be used to replace these modules and functions can be found in the following sections.

### See Also:

**PEP 324** – PEP proposing the subprocess module

### 17.1.1 Using the `subprocess` Module

The recommended approach to invoking subprocesses is to use the following convenience functions for all use cases they can handle. For more advanced use cases, the underlying `Popen` interface can be used directly.

```
subprocess.call (args, *, stdin=None, stdout=None, stderr=None, shell=False)
```

Run the command described by *args*. Wait for command to complete, then return the `returncode` attribute.

The arguments shown above are merely the most common ones, described below in *Frequently Used Arguments* (hence the slightly odd notation in the abbreviated signature). The full function signature is the same as that of the `Popen` constructor - this function passes all supplied arguments directly through to that interface.

Examples:

```
>>> subprocess.call(["ls", "-l"])
0

>>> subprocess.call("exit 1", shell=True)
1
```

**Warning:** Invoking the system shell with `shell=True` can be a security hazard if combined with untrusted input. See the warning under *Frequently Used Arguments* for details.

**Note:** Do not use `stdout=PIPE` or `stderr=PIPE` with this function. As the pipes are not being read in the current process, the child process may block if it generates enough output to a pipe to fill up the OS pipe buffer.

---

`subprocess.check_call` (*args*, \*, *stdin=None*, *stdout=None*, *stderr=None*, *shell=False*)

Run command with arguments. Wait for command to complete. If the return code was zero then return, otherwise raise `CalledProcessError`. The `CalledProcessError` object will have the return code in the `returncode` attribute.

The arguments shown above are merely the most common ones, described below in *Frequently Used Arguments* (hence the slightly odd notation in the abbreviated signature). The full function signature is the same as that of the `Popen` constructor - this function passes all supplied arguments directly through to that interface.

Examples:

```
>>> subprocess.check_call(["ls", "-l"])
0

>>> subprocess.check_call("exit 1", shell=True)
Traceback (most recent call last):
...
subprocess.CalledProcessError: Command 'exit 1' returned non-zero exit status 1
```

New in version 2.5.

**Warning:** Invoking the system shell with `shell=True` can be a security hazard if combined with untrusted input. See the warning under *Frequently Used Arguments* for details.

**Note:** Do not use `stdout=PIPE` or `stderr=PIPE` with this function. As the pipes are not being read in the current process, the child process may block if it generates enough output to a pipe to fill up the OS pipe buffer.

---

`subprocess.check_output` (*args*, \*, *stdin=None*, *stderr=None*, *shell=False*, *universal\_newlines=False*)

Run command with arguments and return its output as a byte string.

If the return code was non-zero it raises a `CalledProcessError`. The `CalledProcessError` object will have the return code in the `returncode` attribute and any output in the `output` attribute.

The arguments shown above are merely the most common ones, described below in *Frequently Used Arguments* (hence the slightly odd notation in the abbreviated signature). The full function signature is largely the same as that of the `Popen` constructor, except that `stdout` is not permitted as it is used internally. All other supplied arguments are passed directly through to the `Popen` constructor.

Examples:

```
>>> subprocess.check_output(["echo", "Hello World!"])
'Hello World!\n'
```

```
>>> subprocess.check_output("exit 1", shell=True)
Traceback (most recent call last):
...
subprocess.CalledProcessError: Command 'exit 1' returned non-zero exit status 1
```

To also capture standard error in the result, use `stderr=subprocess.STDOUT`:

```
>>> subprocess.check_output (
...     "ls non_existent_file; exit 0",
...     stderr=subprocess.STDOUT,
...     shell=True)
'ls: non_existent_file: No such file or directory\n'
```

New in version 2.7.

**Warning:** Invoking the system shell with `shell=True` can be a security hazard if combined with trusted input. See the warning under *Frequently Used Arguments* for details.

---

**Note:** Do not use `stderr=PIPE` with this function. As the pipe is not being read in the current process, the child process may block if it generates enough output to the pipe to fill up the OS pipe buffer.

---

#### `subprocess.PIPE`

Special value that can be used as the *stdin*, *stdout* or *stderr* argument to `Popen` and indicates that a pipe to the standard stream should be opened.

#### `subprocess.STDOUT`

Special value that can be used as the *stderr* argument to `Popen` and indicates that standard error should go into the same handle as standard output.

#### exception `subprocess.CalledProcessError`

Exception raised when a process run by `check_call()` or `check_output()` returns a non-zero exit status.

##### **returncode**

Exit status of the child process.

##### **cmd**

Command that was used to spawn the child process.

##### **output**

Output of the child process if this exception is raised by `check_output()`. Otherwise, `None`.

## Frequently Used Arguments

To support a wide variety of use cases, the `Popen` constructor (and the convenience functions) accept a large number of optional arguments. For most typical use cases, many of these arguments can be safely left at their default values. The arguments that are most commonly needed are:

*args* is required for all calls and should be a string, or a sequence of program arguments. Providing a sequence of arguments is generally preferred, as it allows the module to take care of any required escaping and quoting of arguments (e.g. to permit spaces in file names). If passing a single string, either *shell* must be `True` (see below) or else the string must simply name the program to be executed without specifying any arguments.

*stdin*, *stdout* and *stderr* specify the executed program's standard input, standard output and standard error file handles, respectively. Valid values are `PIPE`, an existing file descriptor (a positive integer), an existing file object, and `None`. `PIPE` indicates that a new pipe to the child should be created. With the default

settings of `None`, no redirection will occur; the child's file handles will be inherited from the parent. Additionally, `stderr` can be `STDOUT`, which indicates that the `stderr` data from the child process should be captured into the same file handle as for `stdout`.

When `stdout` or `stderr` are pipes and `universal_newlines` is `True` then all line endings will be converted to `'\n'` as described for the *universal newlines* `'U'` mode argument to `open()`.

If `shell` is `True`, the specified command will be executed through the shell. This can be useful if you are using Python primarily for the enhanced control flow it offers over most system shells and still want convenient access to other shell features such as shell pipes, filename wildcards, environment variable expansion, and expansion of `~` to a user's home directory. However, note that Python itself offers implementations of many shell-like features (in particular, `glob`, `fnmatch`, `os.walk()`, `os.path.expandvars()`, `os.path.expanduser()`, and `shutil`).

**Warning:** Executing shell commands that incorporate unsanitized input from an untrusted source makes a program vulnerable to *shell injection*, a serious security flaw which can result in arbitrary command execution. For this reason, the use of `shell=True` is **strongly discouraged** in cases where the command string is constructed from external input:

```
>>> from subprocess import call
>>> filename = input("What file would you like to display?\n")
What file would you like to display?
non_existent; rm -rf / #
>>> call("cat " + filename, shell=True) # Uh-oh. This will end badly...
shell=False disables all shell based features, but does not suffer from this vulnerability; see the
Note in the Popen constructor documentation for helpful hints in getting shell=False to work.
```

These options, along with all of the other options, are described in more detail in the `Popen` constructor documentation.

### Popen Constructor

The underlying process creation and management in this module is handled by the `Popen` class. It offers a lot of flexibility so that developers are able to handle the less common cases not covered by the convenience functions.

```
class subprocess.Popen(args, bufsize=0, executable=None, stdin=None, stdout=None, stderr=None,
                       preexec_fn=None, close_fds=False, shell=False, cwd=None, env=None, uni-
                       versal_newlines=False, startupinfo=None, creationflags=0)
```

Arguments are:

`args` should be a string, or a sequence of program arguments. The program to execute is normally the first item in the `args` sequence or the string if a string is given, but can be explicitly set by using the `executable` argument. When `executable` is given, the first item in the `args` sequence is still treated by most programs as the command name, which can then be different from the actual executable name. On Unix, it becomes the display name for the executing program in utilities such as `ps`.

On Unix, with `shell=False` (default): In this case, the `Popen` class uses `os.execvp()` to execute the child program. `args` should normally be a sequence. If a string is specified for `args`, it will be used as the name or path of the program to execute; this will only work if the program is being given no arguments.

---

**Note:** `shlex.split()` can be useful when determining the correct tokenization for `args`, especially in complex cases:

```
>>> import shlex, subprocess
>>> command_line = raw_input()
/bin/vikings -input eggs.txt -output "spam spam.txt" -cmd "echo '$MONEY'"
>>> args = shlex.split(command_line)
```

```
>>> print args
['/bin/vikings', '-input', 'eggs.txt', '-output', 'spam spam.txt', '-cmd', "echo '$MOND
>>> p = subprocess.Popen(args) # Success!
```

Note in particular that options (such as *-input*) and arguments (such as *eggs.txt*) that are separated by whitespace in the shell go in separate list elements, while arguments that need quoting or backslash escaping when used in the shell (such as filenames containing spaces or the *echo* command shown above) are single list elements.

On Unix, with *shell=True*: If *args* is a string, it specifies the command string to execute through the shell. This means that the string must be formatted exactly as it would be when typed at the shell prompt. This includes, for example, quoting or backslash escaping filenames with spaces in them. If *args* is a sequence, the first item specifies the command string, and any additional items will be treated as additional arguments to the shell itself. That is to say, *Popen* does the equivalent of:

```
Popen(['/bin/sh', '-c', args[0], args[1], ...])
```

On Windows: the *Popen* class uses *CreateProcess()* to execute the child program, which operates on strings. If *args* is a sequence, it will be converted to a string in a manner described in *Converting an argument sequence to a string on Windows*.

*bufsize*, if given, has the same meaning as the corresponding argument to the built-in *open()* function: 0 means unbuffered, 1 means line buffered, any other positive value means use a buffer of (approximately) that size. A negative *bufsize* means to use the system default, which usually means fully buffered. The default value for *bufsize* is 0 (unbuffered).

**Note:** If you experience performance issues, it is recommended that you try to enable buffering by setting *bufsize* to either -1 or a large enough positive value (such as 4096).

The *executable* argument specifies the program to execute. It is very seldom needed: Usually, the program to execute is defined by the *args* argument. If *shell=True*, the *executable* argument specifies which shell to use. On Unix, the default shell is */bin/sh*. On Windows, the default shell is specified by the *COMSPEC* environment variable. The only reason you would need to specify *shell=True* on Windows is where the command you wish to execute is actually built in to the shell, eg *dir*, *copy*. You don't need *shell=True* to run a batch file, nor to run a console-based executable.

*stdin*, *stdout* and *stderr* specify the executed program's standard input, standard output and standard error file handles, respectively. Valid values are *PIPE*, an existing file descriptor (a positive integer), an existing file object, and *None*. *PIPE* indicates that a new pipe to the child should be created. With the default settings of *None*, no redirection will occur; the child's file handles will be inherited from the parent. Additionally, *stderr* can be *STDOUT*, which indicates that the *stderr* data from the child process should be captured into the same file handle as for *stdout*.

If *preexec\_fn* is set to a callable object, this object will be called in the child process just before the child is executed. (Unix only)

If *close\_fds* is true, all file descriptors except 0, 1 and 2 will be closed before the child process is executed. (Unix only). Or, on Windows, if *close\_fds* is true then no handles will be inherited by the child process. Note that on Windows, you cannot set *close\_fds* to true and also redirect the standard handles by setting *stdin*, *stdout* or *stderr*.

If *shell* is *True*, the specified command will be executed through the shell.

**Warning:** Enabling this option can be a security hazard if combined with untrusted input. See the warning under *Frequently Used Arguments* for details.

If `cwd` is not `None`, the child's current directory will be changed to `cwd` before it is executed. Note that this directory is not considered when searching the executable, so you can't specify the program's path relative to `cwd`.

If `env` is not `None`, it must be a mapping that defines the environment variables for the new process; these are used instead of inheriting the current process' environment, which is the default behavior.

---

**Note:** If specified, `env` must provide any variables required for the program to execute. On Windows, in order to run a [side-by-side assembly](#) the specified `env` **must** include a valid

`SystemRoot`.

---

If `universal_newlines` is `True`, the file objects `stdout` and `stderr` are opened as text files in *universal newlines* mode. Lines may be terminated by any of `'\n'`, the Unix end-of-line convention, `'\r'`, the old Macintosh convention or `'\r\n'`, the Windows convention. All of these external representations are seen as `'\n'` by the Python program.

---

**Note:** This feature is only available if Python is built with universal newline support (the default). Also, the `newlines` attribute of the file objects `stdout`, `stdin` and `stderr` are not updated by the `communicate()` method.

---

If given, `startupinfo` will be a `STARTUPINFO` object, which is passed to the underlying `CreateProcess` function. `creationflags`, if given, can be `CREATE_NEW_CONSOLE` or `CREATE_NEW_PROCESS_GROUP`. (Windows only)

## Exceptions

Exceptions raised in the child process, before the new program has started to execute, will be re-raised in the parent. Additionally, the exception object will have one extra attribute called `child_traceback`, which is a string containing traceback information from the child's point of view.

The most common exception raised is `OSError`. This occurs, for example, when trying to execute a non-existent file. Applications should prepare for `OSError` exceptions.

A `ValueError` will be raised if `Popen` is called with invalid arguments.

`check_call()` and `check_output()` will raise `CalledProcessError` if the called process returns a non-zero return code.

## Security

Unlike some other `popen` functions, this implementation will never call a system shell implicitly. This means that all characters, including shell metacharacters, can safely be passed to child processes. Obviously, if the shell is invoked explicitly, then it is the application's responsibility to ensure that all whitespace and metacharacters are quoted appropriately.

### 17.1.2 Popen Objects

Instances of the `Popen` class have the following methods:

`Popen.poll()`

Check if child process has terminated. Set and return `returncode` attribute.

`Popen.wait()`

Wait for child process to terminate. Set and return `returncode` attribute.

**Warning:** This will deadlock when using `stdout=PIPE` and/or `stderr=PIPE` and the child process generates enough output to a pipe such that it blocks waiting for the OS pipe buffer to accept more data. Use `communicate()` to avoid that.

`Popen.communicate(input=None)`

Interact with process: Send data to stdin. Read data from stdout and stderr, until end-of-file is reached. Wait for process to terminate. The optional `input` argument should be a string to be sent to the child process, or `None`, if no data should be sent to the child.

`communicate()` returns a tuple `(stdoutdata, stderrdata)`.

Note that if you want to send data to the process's stdin, you need to create the `Popen` object with `stdin=PIPE`. Similarly, to get anything other than `None` in the result tuple, you need to give `stdout=PIPE` and/or `stderr=PIPE` too.

---

**Note:** The data read is buffered in memory, so do not use this method if the data size is large or unlimited.

---

`Popen.send_signal(signal)`

Sends the signal `signal` to the child.

---

**Note:** On Windows, `SIGTERM` is an alias for `terminate()`. `CTRL_C_EVENT` and `CTRL_BREAK_EVENT` can be sent to processes started with a `creationflags` parameter which includes `CREATE_NEW_PROCESS_GROUP`.

---

New in version 2.6.

`Popen.terminate()`

Stop the child. On Posix OSs the method sends `SIGTERM` to the child. On Windows the Win32 API function `TerminateProcess()` is called to stop the child. New in version 2.6.

`Popen.kill()`

Kills the child. On Posix OSs the function sends `SIGKILL` to the child. On Windows `kill()` is an alias for `terminate()`. New in version 2.6.

The following attributes are also available:

**Warning:** Use `communicate()` rather than `.stdin.write`, `.stdout.read` or `.stderr.read` to avoid deadlocks due to any of the other OS pipe buffers filling up and blocking the child process.

`Popen.stdin`

If the `stdin` argument was `PIPE`, this attribute is a file object that provides input to the child process. Otherwise, it is `None`.

`Popen.stdout`

If the `stdout` argument was `PIPE`, this attribute is a file object that provides output from the child process. Otherwise, it is `None`.

`Popen.stderr`

If the `stderr` argument was `PIPE`, this attribute is a file object that provides error output from the child process. Otherwise, it is `None`.

`Popen.pid`

The process ID of the child process.

Note that if you set the *shell* argument to `True`, this is the process ID of the spawned shell.

`Popen`. **returncode**

The child return code, set by `poll()` and `wait()` (and indirectly by `communicate()`). A `None` value indicates that the process hasn't terminated yet.

A negative value `-N` indicates that the child was terminated by signal `N` (Unix only).

### 17.1.3 Windows Popen Helpers

The `STARTUPINFO` class and following constants are only available on Windows.

**class** `subprocess.STARTUPINFO`

Partial support of the Windows `STARTUPINFO` structure is used for `Popen` creation.

**dwFlags**

A bit field that determines whether certain `STARTUPINFO` attributes are used when the process creates a window.

```
si = subprocess.STARTUPINFO()
si.dwFlags = subprocess.STARTF_USESTDHANDLES | subprocess.STARTF_USESHOWWINDOW
```

**hStdInput**

If `dwFlags` specifies `STARTF_USESTDHANDLES`, this attribute is the standard input handle for the process. If `STARTF_USESTDHANDLES` is not specified, the default for standard input is the keyboard buffer.

**hStdOutput**

If `dwFlags` specifies `STARTF_USESTDHANDLES`, this attribute is the standard output handle for the process. Otherwise, this attribute is ignored and the default for standard output is the console window's buffer.

**hStdError**

If `dwFlags` specifies `STARTF_USESTDHANDLES`, this attribute is the standard error handle for the process. Otherwise, this attribute is ignored and the default for standard error is the console window's buffer.

**wShowWindow**

If `dwFlags` specifies `STARTF_USESHOWWINDOW`, this attribute can be any of the values that can be specified in the `nCmdShow` parameter for the `ShowWindow` function, except for `SW_SHOWDEFAULT`. Otherwise, this attribute is ignored.

`SW_HIDE` is provided for this attribute. It is used when `Popen` is called with `shell=True`.

### Constants

The `subprocess` module exposes the following constants.

`subprocess.STD_INPUT_HANDLE`

The standard input device. Initially, this is the console input buffer, `CONIN$`.

`subprocess.STD_OUTPUT_HANDLE`

The standard output device. Initially, this is the active console screen buffer, `CONOUT$`.

`subprocess.STD_ERROR_HANDLE`

The standard error device. Initially, this is the active console screen buffer, `CONOUT$`.

`subprocess.SW_HIDE`

Hides the window. Another window will be activated.

`subprocess.STARTF_USESTDHANDLES`

Specifies that the `STARTUPINFO.hStdInput`, `STARTUPINFO.hStdOutput`, and `STARTUPINFO.hStdError` attributes contain additional information.

`subprocess.STARTF_USESHOWWINDOW`

Specifies that the `STARTUPINFO.wShowWindow` attribute contains additional information.

`subprocess.CREATE_NEW_CONSOLE`

The new process has a new console, instead of inheriting its parent's console (the default).

This flag is always set when `Popen` is created with `shell=True`.

`subprocess.CREATE_NEW_PROCESS_GROUP`

A `Popen` `creationflags` parameter to specify that a new process group will be created. This flag is necessary for using `os.kill()` on the subprocess.

This flag is ignored if `CREATE_NEW_CONSOLE` is specified.

## 17.1.4 Replacing Older Functions with the subprocess Module

In this section, “a becomes b” means that b can be used as a replacement for a.

---

**Note:** All “a” functions in this section fail (more or less) silently if the executed program cannot be found; the “b” replacements raise `OSError` instead.

In addition, the replacements using `check_output()` will fail with a `CalledProcessError` if the requested operation produces a non-zero return code. The output is still available as the `output` attribute of the raised exception.

---

In the following examples, we assume that the relevant functions have already been imported from the `subprocess` module.

### Replacing `/bin/sh` shell backquote

```
output=`mycmd myarg`
# becomes
output = check_output(["mycmd", "myarg"])
```

### Replacing shell pipeline

```
output=`dmesg | grep hda`
# becomes
p1 = Popen(["dmesg"], stdout=PIPE)
p2 = Popen(["grep", "hda"], stdin=p1.stdout, stdout=PIPE)
p1.stdout.close() # Allow p1 to receive a SIGPIPE if p2 exits.
output = p2.communicate()[0]
```

The `p1.stdout.close()` call after starting the `p2` is important in order for `p1` to receive a `SIGPIPE` if `p2` exits before `p1`.

Alternatively, for trusted input, the shell's own pipeline support may still be used directly:

```
output=`dmesg | grep hda`
# becomes
output=check_output("dmesg | grep hda", shell=True)
```

### Replacing `os.system()`

```
sts = os.system("mycmd" + " myarg")
# becomes
sts = call("mycmd" + " myarg", shell=True)
```

Notes:

- Calling the program through the shell is usually not required.

A more realistic example would look like this:

```
try:
    retcode = call("mycmd" + " myarg", shell=True)
    if retcode < 0:
        print >>sys.stderr, "Child was terminated by signal", -retcode
    else:
        print >>sys.stderr, "Child returned", retcode
except OSError, e:
    print >>sys.stderr, "Execution failed:", e
```

### Replacing the `os.spawn` family

`P_NOWAIT` example:

```
pid = os.spawnlp(os.P_NOWAIT, "/bin/mycmd", "mycmd", "myarg")
==>
pid = Popen(["/bin/mycmd", "myarg"]).pid
```

`P_WAIT` example:

```
retcode = os.spawnlp(os.P_WAIT, "/bin/mycmd", "mycmd", "myarg")
==>
retcode = call(["/bin/mycmd", "myarg"])
```

Vector example:

```
os.spawnvp(os.P_NOWAIT, path, args)
==>
Popen([path] + args[1:])
```

Environment example:

```
os.spawnlpe(os.P_NOWAIT, "/bin/mycmd", "mycmd", "myarg", env)
==>
Popen(["/bin/mycmd", "myarg"], env={"PATH": "/usr/bin"})
```

### Replacing `os.popen()`, `os.popen2()`, `os.popen3()`

```
pipe = os.popen("cmd", 'r', bufsize)
==>
pipe = Popen("cmd", shell=True, bufsize=bufsize, stdout=PIPE).stdout
pipe = os.popen("cmd", 'w', bufsize)
==>
pipe = Popen("cmd", shell=True, bufsize=bufsize, stdin=PIPE).stdin
```

```
(child_stdin, child_stdout) = os.popen2("cmd", mode, bufsize)
==>
p = Popen("cmd", shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdin, child_stdout) = (p.stdin, p.stdout)

(child_stdin,
 child_stdout,
 child_stderr) = os.popen3("cmd", mode, bufsize)
==>
p = Popen("cmd", shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, stderr=PIPE, close_fds=True)
(child_stdin,
 child_stdout,
 child_stderr) = (p.stdin, p.stdout, p.stderr)

(child_stdin, child_stdout_and_stderr) = os.popen4("cmd", mode,
                                                  bufsize)
==>
p = Popen("cmd", shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, stderr=STDOUT, close_fds=True)
(child_stdin, child_stdout_and_stderr) = (p.stdin, p.stdout)
```

On Unix, `os.popen2`, `os.popen3` and `os.popen4` also accept a sequence as the command to execute, in which case arguments will be passed directly to the program without shell intervention. This usage can be replaced as follows:

```
(child_stdin, child_stdout) = os.popen2(["/bin/ls", "-l"], mode,
                                         bufsize)
==>
p = Popen(["/bin/ls", "-l"], bufsize=bufsize, stdin=PIPE, stdout=PIPE)
(child_stdin, child_stdout) = (p.stdin, p.stdout)
```

Return code handling translates as follows:

```
pipe = os.popen("cmd", 'w')
...
rc = pipe.close()
if rc is not None and rc >> 8:
    print "There were some errors"
==>
process = Popen("cmd", 'w', shell=True, stdin=PIPE)
...
process.stdin.close()
if process.wait() != 0:
    print "There were some errors"
```

### Replacing functions from the `popen2` module

```
(child_stdout, child_stdin) = popen2.popen2("somestring", bufsize, mode)
==>
p = Popen(["somestring"], shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

On Unix, `popen2` also accepts a sequence as the command to execute, in which case arguments will be passed directly to the program without shell intervention. This usage can be replaced as follows:

```
(child_stdout, child_stdin) = popen2.popen2(["mycmd", "myarg"], bufsize,
                                           mode)
==>
p = Popen(["mycmd", "myarg"], bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

`popen2.Popen3` and `popen2.Popen4` basically work as `subprocess.Popen`, except that:

- `Popen` raises an exception if the execution fails.
- the `capturestderr` argument is replaced with the `stderr` argument.
- `stdin=PIPE` and `stdout=PIPE` must be specified.
- `popen2` closes all file descriptors by default, but you have to specify `close_fds=True` with `Popen`.

### 17.1.5 Notes

#### Converting an argument sequence to a string on Windows

On Windows, an *args* sequence is converted to a string that can be parsed using the following rules (which correspond to the rules used by the MS C runtime):

1. Arguments are delimited by white space, which is either a space or a tab.
2. A string surrounded by double quotation marks is interpreted as a single argument, regardless of white space contained within. A quoted string can be embedded in an argument.
3. A double quotation mark preceded by a backslash is interpreted as a literal double quotation mark.
4. Backslashes are interpreted literally, unless they immediately precede a double quotation mark.
5. If backslashes immediately precede a double quotation mark, every pair of backslashes is interpreted as a literal backslash. If the number of backslashes is odd, the last backslash escapes the next double quotation mark as described in rule 3.

## 17.2 `socket` — Low-level networking interface

This module provides access to the BSD *socket* interface. It is available on all modern Unix systems, Windows, Mac OS X, BeOS, OS/2, and probably additional platforms.

---

**Note:** Some behavior may be platform dependent, since calls are made to the operating system socket APIs.

---

For an introduction to socket programming (in C), see the following papers: An Introductory 4.3BSD Interprocess Communication Tutorial, by Stuart Sechrest and An Advanced 4.3BSD Interprocess Communication Tutorial, by Samuel J. Leffler et al, both in the UNIX Programmer's Manual, Supplementary Documents 1 (sections PS1:7 and PS1:8). The platform-specific reference material for the various socket-related system calls are also a valuable source of information on the details of socket semantics. For Unix, refer to the manual pages; for Windows, see the WinSock (or Winsock 2) specification. For IPv6-ready APIs, readers may want to refer to [RFC 3493](#) titled Basic Socket Interface Extensions for IPv6.

The Python interface is a straightforward transliteration of the Unix system call and library interface for sockets to Python's object-oriented style: the `socket()` function returns a *socket object* whose methods implement the various socket system calls. Parameter types are somewhat higher-level than in the C interface: as with `read()` and

`write()` operations on Python files, buffer allocation on receive operations is automatic, and buffer length is implicit on send operations.

Socket addresses are represented as follows: A single string is used for the `AF_UNIX` address family. A pair (`host`, `port`) is used for the `AF_INET` address family, where `host` is a string representing either a hostname in Internet domain notation like `'daring.cwi.nl'` or an IPv4 address like `'100.50.200.5'`, and `port` is an integer. For `AF_INET6` address family, a four-tuple (`host`, `port`, `flowinfo`, `scopeid`) is used, where `flowinfo` and `scopeid` represents `sin6_flowinfo` and `sin6_scope_id` member in `struct sockaddr_in6` in C. For `socket` module methods, `flowinfo` and `scopeid` can be omitted just for backward compatibility. Note, however, omission of `scopeid` can cause problems in manipulating scoped IPv6 addresses. Other address families are currently not supported. The address format required by a particular socket object is automatically selected based on the address family specified when the socket object was created.

For IPv4 addresses, two special forms are accepted instead of a host address: the empty string represents `INADDR_ANY`, and the string `'<broadcast>'` represents `INADDR_BROADCAST`. The behavior is not available for IPv6 for backward compatibility, therefore, you may want to avoid these if you intend to support IPv6 with your Python programs.

If you use a hostname in the `host` portion of IPv4/v6 socket address, the program may show a nondeterministic behavior, as Python uses the first address returned from the DNS resolution. The socket address will be resolved differently into an actual IPv4/v6 address, depending on the results from DNS resolution and/or the host configuration. For deterministic behavior use a numeric address in `host` portion. New in version 2.5: `AF_NETLINK` sockets are represented as pairs `pid`, `groups`. New in version 2.6: Linux-only support for TIPC is also available using the `AF_TIPC` address family. TIPC is an open, non-IP based networked protocol designed for use in clustered computer environments. Addresses are represented by a tuple, and the fields depend on the address type. The general tuple form is (`addr_type`, `v1`, `v2`, `v3` [, `scope`]), where:

- `addr_type` is one of `:const`; `'TIPC_ADDR_NAMESEQ'`, `TIPC_ADDR_NAME`, or `TIPC_ADDR_ID`.
- `scope` is one of `TIPC_ZONE_SCOPE`, `TIPC_CLUSTER_SCOPE`, and `TIPC_NODE_SCOPE`.
- If `addr_type` is `TIPC_ADDR_NAME`, then `v1` is the server type, `v2` is the port identifier, and `v3` should be 0.

If `addr_type` is `TIPC_ADDR_NAMESEQ`, then `v1` is the server type, `v2` is the lower port number, and `v3` is the upper port number.

If `addr_type` is `TIPC_ADDR_ID`, then `v1` is the node, `v2` is the reference, and `v3` should be set to 0.

All errors raise exceptions. The normal exceptions for invalid argument types and out-of-memory conditions can be raised; errors related to socket or address semantics raise the error `socket.error`.

Non-blocking mode is supported through `setblocking()`. A generalization of this based on timeouts is supported through `settimeout()`.

The module `socket` exports the following constants and functions:

#### exception `socket.error`

This exception is raised for socket-related errors. The accompanying value is either a string telling what went wrong or a pair (`errno`, `string`) representing an error returned by a system call, similar to the value accompanying `os.error`. See the module `errno`, which contains names for the error codes defined by the underlying operating system. Changed in version 2.6: `socket.error` is now a child class of `IOError`.

#### exception `socket.herror`

This exception is raised for address-related errors, i.e. for functions that use `h_errno` in the C API, including `gethostbyname_ex()` and `gethostbyaddr()`.

The accompanying value is a pair (`h_errno`, `string`) representing an error returned by a library call. `string` represents the description of `h_errno`, as returned by the `hstrerror()` C function.

#### exception `socket.gaierror`

This exception is raised for address-related errors, for `getaddrinfo()` and `getnameinfo()`. The accom-

panying value is a pair (*error*, *string*) representing an error returned by a library call. *string* represents the description of *error*, as returned by the `gai_strerror()` C function. The *error* value will match one of the `EAI_*` constants defined in this module.

### exception `socket.timeout`

This exception is raised when a timeout occurs on a socket which has had timeouts enabled via a prior call to `settimeout()`. The accompanying value is a string whose value is currently always “timed out”. New in version 2.3.

`socket.AF_UNIX`

`socket.AF_INET`

`socket.AF_INET6`

These constants represent the address (and protocol) families, used for the first argument to `socket()`. If the `AF_UNIX` constant is not defined then this protocol is unsupported.

`socket.SOCK_STREAM`

`socket.SOCK_DGRAM`

`socket.SOCK_RAW`

`socket.SOCK_RDM`

`socket.SOCK_SEQPACKET`

These constants represent the socket types, used for the second argument to `socket()`. (Only `SOCK_STREAM` and `SOCK_DGRAM` appear to be generally useful.)

`SO_*`

`socket.SOMAXCONN`

`MSG_*`

`SOL_*`

`IPPROTO_*`

`IPPORT_*`

`INADDR_*`

`IP_*`

`IPV6_*`

`EAI_*`

`AI_*`

`NI_*`

`TCP_*`

Many constants of these forms, documented in the Unix documentation on sockets and/or the IP protocol, are also defined in the `socket` module. They are generally used in arguments to the `setsockopt()` and `getsockopt()` methods of socket objects. In most cases, only those symbols that are defined in the Unix header files are defined; for a few symbols, default values are provided.

`SIO_*`

`RCVALL_*`

Constants for Windows' `WSAIoctl()`. The constants are used as arguments to the `ioctl()` method of socket objects. New in version 2.6.

`TIPC_*`

TIPC related constants, matching the ones exported by the C socket API. See the TIPC documentation for more information. New in version 2.6.

`socket.has_ipv6`

This constant contains a boolean value which indicates if IPv6 is supported on this platform. New in version 2.3.

`socket.create_connection(address[, timeout[, source_address]])`

Connect to a TCP service listening on the Internet *address* (a 2-tuple (*host*, *port*)), and return the socket object. This is a higher-level function than `socket.connect()`: if *host* is a non-numeric hostname, it will

try to resolve it for both `AF_INET` and `AF_INET6`, and then try to connect to all possible addresses in turn until a connection succeeds. This makes it easy to write clients that are compatible to both IPv4 and IPv6.

Passing the optional `timeout` parameter will set the timeout on the socket instance before attempting to connect. If no `timeout` is supplied, the global default timeout setting returned by `getdefaulttimeout()` is used.

If supplied, `source_address` must be a 2-tuple (`host`, `port`) for the socket to bind to as its source address before connecting. If `host` or `port` are "" or 0 respectively the OS default behavior will be used. New in version 2.6. Changed in version 2.7: `source_address` was added.

`socket.getaddrinfo(host, port, family=0, socktype=0, proto=0, flags=0)`

Translate the `host/port` argument into a sequence of 5-tuples that contain all the necessary arguments for creating a socket connected to that service. `host` is a domain name, a string representation of an IPv4/v6 address or `None`. `port` is a string service name such as 'http', a numeric port number or `None`. By passing `None` as the value of `host` and `port`, you can pass `NULL` to the underlying C API.

The `family`, `socktype` and `proto` arguments can be optionally specified in order to narrow the list of addresses returned. Passing zero as a value for each of these arguments selects the full range of results. The `flags` argument can be one or several of the `AI_*` constants, and will influence how results are computed and returned. For example, `AI_NUMERICHOST` will disable domain name resolution and will raise an error if `host` is a domain name.

The function returns a list of 5-tuples with the following structure:

```
(family, socktype, proto, canonname, sockaddr)
```

In these tuples, `family`, `socktype`, `proto` are all integers and are meant to be passed to the `socket()` function. `canonname` will be a string representing the canonical name of the `host` if `AI_CANONNAME` is part of the `flags` argument; else `canonname` will be empty. `sockaddr` is a tuple describing a socket address, whose format depends on the returned `family` (a (`address`, `port`) 2-tuple for `AF_INET`, a (`address`, `port`, `flow info`, `scope id`) 4-tuple for `AF_INET6`), and is meant to be passed to the `socket.connect()` method.

The following example fetches address information for a hypothetical TCP connection to `www.python.org` on port 80 (results may differ on your system if IPv6 isn't enabled):

```
>>> socket.getaddrinfo("www.python.org", 80, 0, 0, socket.SOL_TCP)
[(2, 1, 6, '', ('82.94.164.162', 80)),
 (10, 1, 6, '', ('2001:888:2000:d::a2', 80, 0, 0))]
```

New in version 2.2.

`socket.getfqdn([name])`

Return a fully qualified domain name for `name`. If `name` is omitted or empty, it is interpreted as the local host. To find the fully qualified name, the hostname returned by `gethostbyaddr()` is checked, followed by aliases for the host, if available. The first name which includes a period is selected. In case no fully qualified domain name is available, the hostname as returned by `gethostname()` is returned. New in version 2.0.

`socket.gethostbyname(hostname)`

Translate a host name to IPv4 address format. The IPv4 address is returned as a string, such as '100.50.200.5'. If the host name is an IPv4 address itself it is returned unchanged. See `gethostbyname_ex()` for a more complete interface. `gethostbyname()` does not support IPv6 name resolution, and `getaddrinfo()` should be used instead for IPv4/v6 dual stack support.

`socket.gethostbyname_ex(hostname)`

Translate a host name to IPv4 address format, extended interface. Return a triple (`hostname`, `aliaslist`, `ipaddrlist`) where `hostname` is the primary host name responding to the given `ip_address`, `aliaslist` is a (possibly empty) list of alternative host names for the same address, and `ipaddrlist` is a list of IPv4 addresses for the same interface on the same host (often but not always a single address). `gethostbyname_ex()` does not support IPv6 name resolution, and `getaddrinfo()` should be used instead for IPv4/v6 dual stack support.

`socket.gethostname()`

Return a string containing the hostname of the machine where the Python interpreter is currently executing.

If you want to know the current machine's IP address, you may want to use `gethostbyname(gethostname())`. This operation assumes that there is a valid address-to-host mapping for the host, and the assumption does not always hold.

Note: `gethostname()` doesn't always return the fully qualified domain name; use `getfqdn()` (see above).

`socket.gethostbyaddr(ip_address)`

Return a triple (`hostname`, `aliaslist`, `ipaddrlist`) where `hostname` is the primary host name responding to the given `ip_address`, `aliaslist` is a (possibly empty) list of alternative host names for the same address, and `ipaddrlist` is a list of IPv4/v6 addresses for the same interface on the same host (most likely containing only a single address). To find the fully qualified domain name, use the function `getfqdn()`. `gethostbyaddr()` supports both IPv4 and IPv6.

`socket.getnameinfo(sockaddr, flags)`

Translate a socket address `sockaddr` into a 2-tuple (`host`, `port`). Depending on the settings of `flags`, the result can contain a fully-qualified domain name or numeric address representation in `host`. Similarly, `port` can contain a string port name or a numeric port number. New in version 2.2.

`socket.getprotobyname(protocolname)`

Translate an Internet protocol name (for example, `'icmp'`) to a constant suitable for passing as the (optional) third argument to the `socket()` function. This is usually only needed for sockets opened in "raw" mode (`SOCK_RAW`); for the normal socket modes, the correct protocol is chosen automatically if the protocol is omitted or zero.

`socket.getservbyname(servicename[, protocolname])`

Translate an Internet service name and protocol name to a port number for that service. The optional protocol name, if given, should be `'tcp'` or `'udp'`, otherwise any protocol will match.

`socket.getservbyport(port[, protocolname])`

Translate an Internet port number and protocol name to a service name for that service. The optional protocol name, if given, should be `'tcp'` or `'udp'`, otherwise any protocol will match.

`socket.socket([family[, type[, proto]]])`

Create a new socket using the given address family, socket type and protocol number. The address family should be `AF_INET` (the default), `AF_INET6` or `AF_UNIX`. The socket type should be `SOCK_STREAM` (the default), `SOCK_DGRAM` or perhaps one of the other `SOCK_` constants. The protocol number is usually zero and may be omitted in that case.

`socket.socketpair([family[, type[, proto]]])`

Build a pair of connected socket objects using the given address family, socket type, and protocol number. Address family, socket type, and protocol number are as for the `socket()` function above. The default family is `AF_UNIX` if defined on the platform; otherwise, the default is `AF_INET`. Availability: Unix. New in version 2.4.

`socket.fromfd(fd, family, type[, proto])`

Duplicate the file descriptor `fd` (an integer as returned by a file object's `fileno()` method) and build a socket object from the result. Address family, socket type and protocol number are as for the `socket()` function above. The file descriptor should refer to a socket, but this is not checked — subsequent operations on the object may fail if the file descriptor is invalid. This function is rarely needed, but can be used to get or set socket options on a socket passed to a program as standard input or output (such as a server started by the Unix `inetd` daemon). The socket is assumed to be in blocking mode. Availability: Unix.

`socket.ntohl(x)`

Convert 32-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

`socket.ntohs(x)`

Convert 16-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

`socket.htonl(x)`

Convert 32-bit positive integers from host to network byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

`socket.htons(x)`

Convert 16-bit positive integers from host to network byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

`socket.inet_aton(ip_string)`

Convert an IPv4 address from dotted-quad string format (for example, '123.45.67.89') to 32-bit packed binary format, as a string four characters in length. This is useful when conversing with a program that uses the standard C library and needs objects of type `struct in_addr`, which is the C type for the 32-bit packed binary this function returns.

`inet_aton()` also accepts strings with less than three dots; see the Unix manual page *inet(3)* for details.

If the IPv4 address string passed to this function is invalid, `socket.error` will be raised. Note that exactly what is valid depends on the underlying C implementation of `inet_aton()`.

`inet_aton()` does not support IPv6, and `inet_pton()` should be used instead for IPv4/v6 dual stack support.

`socket.inet_ntoa(packed_ip)`

Convert a 32-bit packed IPv4 address (a string four characters in length) to its standard dotted-quad string representation (for example, '123.45.67.89'). This is useful when conversing with a program that uses the standard C library and needs objects of type `struct in_addr`, which is the C type for the 32-bit packed binary data this function takes as an argument.

If the string passed to this function is not exactly 4 bytes in length, `socket.error` will be raised. `inet_ntoa()` does not support IPv6, and `inet_ntop()` should be used instead for IPv4/v6 dual stack support.

`socket.inet_pton(address_family, ip_string)`

Convert an IP address from its family-specific string format to a packed, binary format. `inet_pton()` is useful when a library or network protocol calls for an object of type `struct in_addr` (similar to `inet_aton()`) or `struct in6_addr`.

Supported values for *address\_family* are currently `AF_INET` and `AF_INET6`. If the IP address string *ip\_string* is invalid, `socket.error` will be raised. Note that exactly what is valid depends on both the value of *address\_family* and the underlying implementation of `inet_pton()`.

Availability: Unix (maybe not all platforms). New in version 2.3.

`socket.inet_ntop(address_family, packed_ip)`

Convert a packed IP address (a string of some number of characters) to its standard, family-specific string representation (for example, '7.10.0.5' or '5aef:2b::8') `inet_ntop()` is useful when a library or network protocol returns an object of type `struct in_addr` (similar to `inet_ntoa()`) or `struct in6_addr`.

Supported values for *address\_family* are currently `AF_INET` and `AF_INET6`. If the string *packed\_ip* is not the correct length for the specified address family, `ValueError` will be raised. A `socket.error` is raised for errors from the call to `inet_ntop()`.

Availability: Unix (maybe not all platforms). New in version 2.3.

`socket.getdefaulttimeout()`

Return the default timeout in seconds (float) for new socket objects. A value of `None` indicates that new socket

objects have no timeout. When the socket module is first imported, the default is `None`. New in version 2.3.

`socket.setdefaulttimeout(timeout)`

Set the default timeout in seconds (float) for new socket objects. A value of `None` indicates that new socket objects have no timeout. When the socket module is first imported, the default is `None`. New in version 2.3.

`socket.SocketType`

This is a Python type object that represents the socket object type. It is the same as `type(socket(...))`.

**See Also:**

**Module `SocketServer`** Classes that simplify writing network servers.

**Module `ssl`** A TLS/SSL wrapper for socket objects.

## 17.2.1 Socket Objects

Socket objects have the following methods. Except for `makefile()` these correspond to Unix system calls applicable to sockets.

`socket.accept()`

Accept a connection. The socket must be bound to an address and listening for connections. The return value is a pair `(conn, address)` where `conn` is a new socket object usable to send and receive data on the connection, and `address` is the address bound to the socket on the other end of the connection.

`socket.bind(address)`

Bind the socket to `address`. The socket must not already be bound. (The format of `address` depends on the address family — see above.)

---

**Note:** This method has historically accepted a pair of parameters for `AF_INET` addresses instead of only a tuple. This was never intentional and is no longer available in Python 2.0 and later.

---

`socket.close()`

Close the socket. All future operations on the socket object will fail. The remote end will receive no more data (after queued data is flushed). Sockets are automatically closed when they are garbage-collected.

---

**Note:** `close()` releases the resource associated with a connection but does not necessarily close the connection immediately. If you want to close the connection in a timely fashion, call `shutdown()` before `close()`.

---

`socket.connect(address)`

Connect to a remote socket at `address`. (The format of `address` depends on the address family — see above.)

---

**Note:** This method has historically accepted a pair of parameters for `AF_INET` addresses instead of only a tuple. This was never intentional and is no longer available in Python 2.0 and later.

---

`socket.connect_ex(address)`

Like `connect(address)`, but return an error indicator instead of raising an exception for errors returned by the C-level `connect()` call (other problems, such as “host not found,” can still raise exceptions). The error indicator is 0 if the operation succeeded, otherwise the value of the `errno` variable. This is useful to support, for example, asynchronous connects.

---

**Note:** This method has historically accepted a pair of parameters for `AF_INET` addresses instead of only a tuple. This was never intentional and is no longer available in Python 2.0 and later.

---

`socket.fileno()`

Return the socket's file descriptor (a small integer). This is useful with `select.select()`.

Under Windows the small integer returned by this method cannot be used where a file descriptor can be used (such as `os.fdopen()`). Unix does not have this limitation.

`socket.getpeername()`

Return the remote address to which the socket is connected. This is useful to find out the port number of a remote IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.) On some systems this function is not supported.

`socket.getsockname()`

Return the socket's own address. This is useful to find out the port number of an IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.)

`socket.getsockopt(level, optname[, buflen])`

Return the value of the given socket option (see the Unix man page `getsockopt(2)`). The needed symbolic constants (`SO_*` etc.) are defined in this module. If `buflen` is absent, an integer option is assumed and its integer value is returned by the function. If `buflen` is present, it specifies the maximum length of the buffer used to receive the option in, and this buffer is returned as a string. It is up to the caller to decode the contents of the buffer (see the optional built-in module `struct` for a way to decode C structures encoded as strings).

`socket.ioctl(control, option)`

**Platform** Windows

The `ioctl()` method is a limited interface to the `WSAIoctl` system interface. Please refer to the [Win32 documentation](#) for more information.

On other platforms, the generic `fcntl.fcntl()` and `fcntl.ioctl()` functions may be used; they accept a socket object as their first argument. New in version 2.6.

`socket.listen(backlog)`

Listen for connections made to the socket. The `backlog` argument specifies the maximum number of queued connections and should be at least 0; the maximum value is system-dependent (usually 5), the minimum value is forced to 0.

`socket.makefile([mode[, bufsize]])`

Return a *file object* associated with the socket. (File objects are described in [File Objects](#).) The file object references a `dup()`ped version of the socket file descriptor, so the file object and socket object may be closed or garbage-collected independently. The socket must be in blocking mode (it can not have a timeout). The optional `mode` and `bufsize` arguments are interpreted the same way as by the built-in `file()` function.

---

**Note:** On Windows, the file-like object created by `makefile()` cannot be used where a file object with a file descriptor is expected, such as the stream arguments of `subprocess.Popen()`.

---

`socket.recv(bufsize[, flags])`

Receive data from the socket. The return value is a string representing the data received. The maximum amount of data to be received at once is specified by `bufsize`. See the Unix manual page `recv(2)` for the meaning of the optional argument `flags`; it defaults to zero.

---

**Note:** For best match with hardware and network realities, the value of `bufsize` should be a relatively small power of 2, for example, 4096.

---

`socket.recvfrom(bufsize[, flags])`

Receive data from the socket. The return value is a pair (`string, address`) where `string` is a string representing the data received and `address` is the address of the socket sending the data. See the Unix manual

page `recv(2)` for the meaning of the optional argument `flags`; it defaults to zero. (The format of `address` depends on the address family — see above.)

`socket.recvfrom_into(buffer[, nbytes[, flags]])`

Receive data from the socket, writing it into `buffer` instead of creating a new string. The return value is a pair (`nbytes`, `address`) where `nbytes` is the number of bytes received and `address` is the address of the socket sending the data. See the Unix manual page `recv(2)` for the meaning of the optional argument `flags`; it defaults to zero. (The format of `address` depends on the address family — see above.) New in version 2.5.

`socket.recv_into(buffer[, nbytes[, flags]])`

Receive up to `nbytes` bytes from the socket, storing the data into a buffer rather than creating a new string. If `nbytes` is not specified (or 0), receive up to the size available in the given buffer. Returns the number of bytes received. See the Unix manual page `recv(2)` for the meaning of the optional argument `flags`; it defaults to zero. New in version 2.5.

`socket.send(string[, flags])`

Send data to the socket. The socket must be connected to a remote socket. The optional `flags` argument has the same meaning as for `recv()` above. Returns the number of bytes sent. Applications are responsible for checking that all data has been sent; if only some of the data was transmitted, the application needs to attempt delivery of the remaining data. For further information on this concept, consult the *socket-howto*.

`socket.sendall(string[, flags])`

Send data to the socket. The socket must be connected to a remote socket. The optional `flags` argument has the same meaning as for `recv()` above. Unlike `send()`, this method continues to send data from `string` until either all data has been sent or an error occurs. `None` is returned on success. On error, an exception is raised, and there is no way to determine how much data, if any, was successfully sent.

`socket.sendto(string, address)`

`socket.sendto(string, flags, address)`

Send data to the socket. The socket should not be connected to a remote socket, since the destination socket is specified by `address`. The optional `flags` argument has the same meaning as for `recv()` above. Return the number of bytes sent. (The format of `address` depends on the address family — see above.)

`socket.setblocking(flag)`

Set blocking or non-blocking mode of the socket: if `flag` is 0, the socket is set to non-blocking, else to blocking mode. Initially all sockets are in blocking mode. In non-blocking mode, if a `recv()` call doesn't find any data, or if a `send()` call can't immediately dispose of the data, a `error` exception is raised; in blocking mode, the calls block until they can proceed. `s.setblocking(0)` is equivalent to `s.settimeout(0.0)`; `s.setblocking(1)` is equivalent to `s.settimeout(None)`.

`socket.settimeout(value)`

Set a timeout on blocking socket operations. The `value` argument can be a nonnegative float expressing seconds, or `None`. If a float is given, subsequent socket operations will raise a `timeout` exception if the timeout period `value` has elapsed before the operation has completed. Setting a timeout of `None` disables timeouts on socket operations. `s.settimeout(0.0)` is equivalent to `s.setblocking(0)`; `s.settimeout(None)` is equivalent to `s.setblocking(1)`. New in version 2.3.

`socket.gettimeout()`

Return the timeout in seconds (float) associated with socket operations, or `None` if no timeout is set. This reflects the last call to `setblocking()` or `settimeout()`. New in version 2.3.

Some notes on socket blocking and timeouts: A socket object can be in one of three modes: blocking, non-blocking, or timeout. Sockets are always created in blocking mode. In blocking mode, operations block until complete or the system returns an error (such as connection timed out). In non-blocking mode, operations fail (with an error that is unfortunately system-dependent) if they cannot be completed immediately. In timeout mode, operations fail if they cannot be completed within the timeout specified for the socket or if the system returns an error. The `setblocking()` method is simply a shorthand for certain `settimeout()` calls.

Timeout mode internally sets the socket in non-blocking mode. The blocking and timeout modes are shared between file descriptors and socket objects that refer to the same network endpoint. A consequence of this is that file objects returned by the `makefile()` method must only be used when the socket is in blocking mode; in timeout or non-blocking mode file operations that cannot be completed immediately will fail.

Note that the `connect()` operation is subject to the timeout setting, and in general it is recommended to call `settimeout()` before calling `connect()` or pass a timeout parameter to `create_connection()`. The system network stack may return a connection timeout error of its own regardless of any Python socket timeout setting.

`socket.setsockopt` (*level, optname, value*)

Set the value of the given socket option (see the Unix manual page *setsockopt(2)*). The needed symbolic constants are defined in the `socket` module (`SO_*` etc.). The value can be an integer or a string representing a buffer. In the latter case it is up to the caller to ensure that the string contains the proper bits (see the optional built-in module `struct` for a way to encode C structures as strings).

`socket.shutdown` (*how*)

Shut down one or both halves of the connection. If *how* is `SHUT_RD`, further receives are disallowed. If *how* is `SHUT_WR`, further sends are disallowed. If *how* is `SHUT_RDWR`, further sends and receives are disallowed. Depending on the platform, shutting down one half of the connection can also close the opposite half (e.g. on Mac OS X, `shutdown(SHUT_WR)` does not allow further reads on the other end of the connection).

Note that there are no methods `read()` or `write()`; use `recv()` and `send()` without *flags* argument instead.

Socket objects also have these (read-only) attributes that correspond to the values given to the `socket` constructor.

`socket.family`

The socket family. New in version 2.5.

`socket.type`

The socket type. New in version 2.5.

`socket.proto`

The socket protocol. New in version 2.5.

## 17.2.2 Example

Here are four minimal example programs using the TCP/IP protocol: a server that echoes all data that it receives back (servicing only one client), and a client using it. Note that a server must perform the sequence `socket()`, `bind()`, `listen()`, `accept()` (possibly repeating the `accept()` to service more than one client), while a client only needs the sequence `socket()`, `connect()`. Also note that the server does not `sendall()/recv()` on the socket it is listening on but on the new socket returned by `accept()`.

The first two examples support IPv4 only.

```
# Echo server program
```

```
import socket
```

```
HOST = '' # Symbolic name meaning all available interfaces
```

```
PORT = 50007 # Arbitrary non-privileged port
```

```
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
```

```
s.bind((HOST, PORT))
```

```
s.listen(1)
```

```
conn, addr = s.accept()
```

```
print 'Connected by', addr
```

```
while 1:
```

```
    data = conn.recv(1024)
```

```
    if not data: break
```

```
    conn.sendall(data)
conn.close()

# Echo client program
import socket

HOST = 'daring.cwi.nl'      # The remote host
PORT = 50007                # The same port as used by the server
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect((HOST, PORT))
s.sendall('Hello, world')
data = s.recv(1024)
s.close()
print 'Received', repr(data)
```

The next two examples are identical to the above two, but support both IPv4 and IPv6. The server side will listen to the first address family available (it should listen to both instead). On most of IPv6-ready systems, IPv6 will take precedence and the server may not accept IPv4 traffic. The client side will try to connect to the all addresses returned as a result of the name resolution, and sends traffic to the first one connected successfully.

```
# Echo server program
import socket
import sys

HOST = None                  # Symbolic name meaning all available interfaces
PORT = 50007                # Arbitrary non-privileged port
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_UNSPEC,
                              socket.SOCK_STREAM, 0, socket.AI_PASSIVE):
    af, socktype, proto, canonname, sa = res
    try:
        s = socket.socket(af, socktype, proto)
    except socket.error, msg:
        s = None
        continue
    try:
        s.bind(sa)
        s.listen(1)
    except socket.error, msg:
        s.close()
        s = None
        continue
    break
if s is None:
    print 'could not open socket'
    sys.exit(1)
conn, addr = s.accept()
print 'Connected by', addr
while 1:
    data = conn.recv(1024)
    if not data: break
    conn.send(data)
conn.close()

# Echo client program
import socket
```

```

import sys

HOST = 'daring.cwi.nl'      # The remote host
PORT = 50007                # The same port as used by the server
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_UNSPEC, socket.SOCK_STREAM):
    af, socktype, proto, canonname, sa = res
    try:
        s = socket.socket(af, socktype, proto)
    except socket.error, msg:
        s = None
        continue
    try:
        s.connect(sa)
    except socket.error, msg:
        s.close()
        s = None
        continue
    break
if s is None:
    print 'could not open socket'
    sys.exit(1)
s.sendall('Hello, world')
data = s.recv(1024)
s.close()
print 'Received', repr(data)

```

The last example shows how to write a very simple network sniffer with raw sockets on Windows. The example requires administrator privileges to modify the interface:

```

import socket

# the public network interface
HOST = socket.gethostbyname(socket.gethostname())

# create a raw socket and bind it to the public interface
s = socket.socket(socket.AF_INET, socket.SOCK_RAW, socket.IPPROTO_IP)
s.bind((HOST, 0))

# Include IP headers
s.setsockopt(socket.IPPROTO_IP, socket.IP_HDRINCL, 1)

# receive all packages
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_ON)

# receive a package
print s.recvfrom(65565)

# disabled promiscuous mode
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_OFF)

```

Running an example several times with too small delay between executions, could lead to this error:

```
socket.error: [Errno 98] Address already in use
```

This is because the previous execution has left the socket in a `TIME_WAIT` state, and can't be immediately reused.

There is a `socket` flag to set, in order to prevent this, `socket.SO_REUSEADDR`:

```
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.bind((HOST, PORT))
```

the `SO_REUSEADDR` flag tells the kernel to reuse a local socket in `TIME_WAIT` state, without waiting for its natural timeout to expire.

## 17.3 `ssl` — TLS/SSL wrapper for socket objects

New in version 2.6. **Source code:** [Lib/ssl.py](#)

---

This module provides access to Transport Layer Security (often known as “Secure Sockets Layer”) encryption and peer authentication facilities for network sockets, both client-side and server-side. This module uses the OpenSSL library. It is available on all modern Unix systems, Windows, Mac OS X, and probably additional platforms, as long as OpenSSL is installed on that platform.

---

**Note:** Some behavior may be platform dependent, since calls are made to the operating system socket APIs. The installed version of OpenSSL may also cause variations in behavior.

---

This section documents the objects and functions in the `ssl` module; for more general information about TLS, SSL, and certificates, the reader is referred to the documents in the “See Also” section at the bottom.

This module provides a class, `ssl.SSLSocket`, which is derived from the `socket.socket` type, and provides a socket-like wrapper that also encrypts and decrypts the data going over the socket with SSL. It supports additional `read()` and `write()` methods, along with a method, `getpeercert()`, to retrieve the certificate of the other side of the connection, and a method, `cipher()`, to retrieve the cipher being used for the secure connection.

### 17.3.1 Functions, Constants, and Exceptions

#### exception `ssl.SSLError`

Raised to signal an error from the underlying SSL implementation. This signifies some problem in the higher-level encryption and authentication layer that’s superimposed on the underlying network connection. This error is a subtype of `socket.error`, which in turn is a subtype of `IOError`.

`ssl.wrap_socket(sock, keyfile=None, certfile=None, server_side=False, cert_reqs=CERT_NONE, ssl_version={see docs}, ca_certs=None, do_handshake_on_connect=True, suppress_ragged_eofs=True, ciphers=None)`

Takes an instance `sock` of `socket.socket`, and returns an instance of `ssl.SSLSocket`, a subtype of `socket.socket`, which wraps the underlying socket in an SSL context. For client-side sockets, the context construction is lazy; if the underlying socket isn’t connected yet, the context construction will be performed after `connect()` is called on the socket. For server-side sockets, if the socket has no remote peer, it is assumed to be a listening socket, and the server-side SSL wrapping is automatically performed on client connections accepted via the `accept()` method. `wrap_socket()` may raise `SSLError`.

The `keyfile` and `certfile` parameters specify optional files which contain a certificate to be used to identify the local side of the connection. See the discussion of *Certificates* for more information on how the certificate is stored in the `certfile`.

Often the private key is stored in the same file as the certificate; in this case, only the `certfile` parameter need be passed. If the private key is stored in a separate file, both parameters must be used. If the private key is stored in the `certfile`, it should come before the first certificate in the certificate chain:

```

-----BEGIN RSA PRIVATE KEY-----
... (private key in base64 encoding) ...
-----END RSA PRIVATE KEY-----
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----

```

The parameter `server_side` is a boolean which identifies whether server-side or client-side behavior is desired from this socket.

The parameter `cert_reqs` specifies whether a certificate is required from the other side of the connection, and whether it will be validated if provided. It must be one of the three values `CERT_NONE` (certificates ignored), `CERT_OPTIONAL` (not required, but validated if provided), or `CERT_REQUIRED` (required and validated). If the value of this parameter is not `CERT_NONE`, then the `ca_certs` parameter must point to a file of CA certificates.

The `ca_certs` file contains a set of concatenated “certification authority” certificates, which are used to validate certificates passed from the other end of the connection. See the discussion of *Certificates* for more information about how to arrange the certificates in this file.

The parameter `ssl_version` specifies which version of the SSL protocol to use. Typically, the server chooses a particular protocol version, and the client must adapt to the server’s choice. Most of the versions are not interoperable with the other versions. If not specified, the default is `PROTOCOL_SSLv23`; it provides the most compatibility with other versions.

Here’s a table showing which versions in a client (down the side) can connect to which versions in a server (along the top):

<i>client / server</i>	<b>SSLv2</b>	<b>SSLv3</b>	<b>SSLv23</b>	<b>TLSv1</b>
<i>SSLv2</i>	yes	no	yes	no
<i>SSLv3</i>	no	yes	yes	no
<i>SSLv23</i>	yes	no	yes	no
<i>TLSv1</i>	no	no	yes	yes

**Note:** Which connections succeed will vary depending on the version of OpenSSL. For instance, in some older versions of OpenSSL (such as 0.9.7l on OS X 10.4), an SSLv2 client could not connect to an SSLv23 server. Another example: beginning with OpenSSL 1.0.0, an SSLv23 client will not actually attempt SSLv2 connections unless you explicitly enable SSLv2 ciphers; for example, you might specify "ALL" or "SSLv2" as the *ciphers* parameter to enable them.

The *ciphers* parameter sets the available ciphers for this SSL object. It should be a string in the [OpenSSL cipher list format](#).

The parameter `do_handshake_on_connect` specifies whether to do the SSL handshake automatically after doing a `socket.connect()`, or whether the application program will call it explicitly, by invoking the `SSLSocket.do_handshake()` method. Calling `SSLSocket.do_handshake()` explicitly gives the program control over the blocking behavior of the socket I/O involved in the handshake.

The parameter `suppress_ragged_eofs` specifies how the `SSLSocket.read()` method should signal unexpected EOF from the other end of the connection. If specified as `True` (the default), it returns a normal EOF in response to unexpected EOF errors raised from the underlying socket; if `False`, it will raise the exceptions back to the caller. Changed in version 2.7: New optional argument *ciphers*.

#### `ssl.RAND_status()`

Returns `True` if the SSL pseudo-random number generator has been seeded with ‘enough’ randomness, and `False` otherwise. You can use `ssl.RAND_egd()` and `ssl.RAND_add()` to increase the randomness of the pseudo-random number generator.

**ssl.RAND\_egd** (*path*)

If you are running an entropy-gathering daemon (EGD) somewhere, and `path` is the pathname of a socket connection open to it, this will read 256 bytes of randomness from the socket, and add it to the SSL pseudo-random number generator to increase the security of generated secret keys. This is typically only necessary on systems without better sources of randomness.

See <http://egd.sourceforge.net/> or <http://prngd.sourceforge.net/> for sources of entropy-gathering daemons.

**ssl.RAND\_add** (*bytes, entropy*)

Mixes the given `bytes` into the SSL pseudo-random number generator. The parameter `entropy` (a float) is a lower bound on the entropy contained in string (so you can always use `0.0`). See [RFC 1750](#) for more information on sources of entropy.

**ssl.cert\_time\_to\_seconds** (*timestring*)

Returns a floating-point value containing a normal seconds-after-the-epoch time value, given the time-string representing the “notBefore” or “notAfter” date from a certificate.

Here’s an example:

```
>>> import ssl
>>> ssl.cert_time_to_seconds("May  9 00:00:00 2007 GMT")
1178694000.0
>>> import time
>>> time.ctime(ssl.cert_time_to_seconds("May  9 00:00:00 2007 GMT"))
'Wed May  9 00:00:00 2007'
>>>
```

**ssl.get\_server\_certificate** (*addr, ssl\_version=PROTOCOL\_SSLv3, ca\_certs=None*)

Given the address `addr` of an SSL-protected server, as a (*hostname, port-number*) pair, fetches the server’s certificate, and returns it as a PEM-encoded string. If `ssl_version` is specified, uses that version of the SSL protocol to attempt to connect to the server. If `ca_certs` is specified, it should be a file containing a list of root certificates, the same format as used for the same parameter in `wrap_socket()`. The call will attempt to validate the server certificate against that set of root certificates, and will fail if the validation attempt fails.

**ssl.DER\_cert\_to\_PEM\_cert** (*DER\_cert\_bytes*)

Given a certificate as a DER-encoded blob of bytes, returns a PEM-encoded string version of the same certificate.

**ssl.PEM\_cert\_to\_DER\_cert** (*PEM\_cert\_string*)

Given a certificate as an ASCII PEM string, returns a DER-encoded sequence of bytes for that same certificate.

**ssl.CERT\_NONE**

Value to pass to the `cert_reqs` parameter to `sslobject()` when no certificates will be required or validated from the other side of the socket connection.

**ssl.CERT\_OPTIONAL**

Value to pass to the `cert_reqs` parameter to `sslobject()` when no certificates will be required from the other side of the socket connection, but if they are provided, will be validated. Note that use of this setting requires a valid certificate validation file also be passed as a value of the `ca_certs` parameter.

**ssl.CERT\_REQUIRED**

Value to pass to the `cert_reqs` parameter to `sslobject()` when certificates will be required from the other side of the socket connection. Note that use of this setting requires a valid certificate validation file also be passed as a value of the `ca_certs` parameter.

**ssl.PROTOCOL\_SSLv2**

Selects SSL version 2 as the channel encryption protocol.

This protocol is not available if OpenSSL is compiled with `OPENSSL_NO_SSL2` flag.

**Warning:** SSL version 2 is insecure. Its use is highly discouraged.

`ssl.PROTOCOL_SSLv23`

Selects SSL version 2 or 3 as the channel encryption protocol. This is a setting to use with servers for maximum compatibility with the other end of an SSL connection, but it may cause the specific ciphers chosen for the encryption to be of fairly low quality.

`ssl.PROTOCOL_SSLv3`

Selects SSL version 3 as the channel encryption protocol. For clients, this is the maximally compatible SSL variant.

`ssl.PROTOCOL_TLSv1`

Selects TLS version 1 as the channel encryption protocol. This is the most modern version, and probably the best choice for maximum protection, if both sides can speak it.

`ssl.OPENSSL_VERSION`

The version string of the OpenSSL library loaded by the interpreter:

```
>>> ssl.OPENSSL_VERSION
'OpenSSL 0.9.8k 25 Mar 2009'
```

New in version 2.7.

`ssl.OPENSSL_VERSION_INFO`

A tuple of five integers representing version information about the OpenSSL library:

```
>>> ssl.OPENSSL_VERSION_INFO
(0, 9, 8, 11, 15)
```

New in version 2.7.

`ssl.OPENSSL_VERSION_NUMBER`

The raw version number of the OpenSSL library, as a single integer:

```
>>> ssl.OPENSSL_VERSION_NUMBER
9470143L
>>> hex(ssl.OPENSSL_VERSION_NUMBER)
'0x9080bfL'
```

New in version 2.7.

## 17.3.2 SSLSocket Objects

`SSLSocket.read([nbytes=1024])`

Reads up to `nbytes` bytes from the SSL-encrypted channel and returns them.

`SSLSocket.write(data)`

Writes the `data` to the other side of the connection, using the SSL channel to encrypt. Returns the number of bytes written.

`SSLSocket.getpeercert(binary_form=False)`

If there is no certificate for the peer on the other end of the connection, returns `None`.

If the parameter `binary_form` is `False`, and a certificate was received from the peer, this method returns a `dict` instance. If the certificate was not validated, the dict is empty. If the certificate was validated, it returns a dict with the keys `subject` (the principal for which the certificate was issued), and `notAfter` (the time

after which the certificate should not be trusted). The certificate was already validated, so the `notBefore` and `issuer` fields are not returned. If a certificate contains an instance of the *Subject Alternative Name* extension (see [RFC 3280](#)), there will also be a `subjectAltName` key in the dictionary.

The “subject” field is a tuple containing the sequence of relative distinguished names (RDNs) given in the certificate’s data structure for the principal, and each RDN is a sequence of name-value pairs:

```
{'notAfter': 'Feb 16 16:54:50 2013 GMT',
 'subject': (((('countryName', u'US'),),),
              (('stateOrProvinceName', u'Delaware'),),),
              (('localityName', u'Wilmington'),),),
              (('organizationName', u'Python Software Foundation'),),),
              (('organizationalUnitName', u'SSL'),),),
              (('commonName', u'somemachine.python.org'),),),)}
```

If the `binary_form` parameter is `True`, and a certificate was provided, this method returns the DER-encoded form of the entire certificate as a sequence of bytes, or `None` if the peer did not provide a certificate. This return value is independent of validation; if validation was required (`CERT_OPTIONAL` or `CERT_REQUIRED`), it will have been validated, but if `CERT_NONE` was used to establish the connection, the certificate, if present, will not have been validated.

`SSLSocket.cipher()`

Returns a three-value tuple containing the name of the cipher being used, the version of the SSL protocol that defines its use, and the number of secret bits being used. If no connection has been established, returns `None`.

`SSLSocket.do_handshake()`

Perform a TLS/SSL handshake. If this is used with a non-blocking socket, it may raise `SSLError` with an `arg[0]` of `SSL_ERROR_WANT_READ` or `SSL_ERROR_WANT_WRITE`, in which case it must be called again until it completes successfully. For example, to simulate the behavior of a blocking socket, one might write:

```
while True:
    try:
        s.do_handshake()
        break
    except ssl.SSLError, err:
        if err.args[0] == ssl.SSL_ERROR_WANT_READ:
            select.select([s], [], [])
        elif err.args[0] == ssl.SSL_ERROR_WANT_WRITE:
            select.select([], [s], [])
        else:
            raise
```

`SSLSocket.unwrap()`

Performs the SSL shutdown handshake, which removes the TLS layer from the underlying socket, and returns the underlying socket object. This can be used to go from encrypted operation over a connection to unencrypted. The socket instance returned should always be used for further communication with the other side of the connection, rather than the original socket instance (which may not function properly after the `unwrap`).

### 17.3.3 Certificates

Certificates in general are part of a public-key / private-key system. In this system, each *principal*, (which may be a machine, or a person, or an organization) is assigned a unique two-part encryption key. One part of the key is public, and is called the *public key*; the other part is kept secret, and is called the *private key*. The two parts are related, in that if you encrypt a message with one of the parts, you can decrypt it with the other part, and **only** with the other part.

A certificate contains information about two principals. It contains the name of a *subject*, and the subject's public key. It also contains a statement by a second principal, the *issuer*, that the subject is who he claims to be, and that this is indeed the subject's public key. The issuer's statement is signed with the issuer's private key, which only the issuer knows. However, anyone can verify the issuer's statement by finding the issuer's public key, decrypting the statement with it, and comparing it to the other information in the certificate. The certificate also contains information about the time period over which it is valid. This is expressed as two fields, called "notBefore" and "notAfter".

In the Python use of certificates, a client or server can use a certificate to prove who they are. The other side of a network connection can also be required to produce a certificate, and that certificate can be validated to the satisfaction of the client or server that requires such validation. The connection attempt can be set to raise an exception if the validation fails. Validation is done automatically, by the underlying OpenSSL framework; the application need not concern itself with its mechanics. But the application does usually need to provide sets of certificates to allow this process to take place.

Python uses files to contain certificates. They should be formatted as "PEM" (see [RFC 1422](#)), which is a base-64 encoded form wrapped with a header line and a footer line:

```
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----
```

The Python files which contain certificates can contain a sequence of certificates, sometimes called a *certificate chain*. This chain should start with the specific certificate for the principal who "is" the client or server, and then the certificate for the issuer of that certificate, and then the certificate for the issuer of *that* certificate, and so on up the chain till you get to a certificate which is *self-signed*, that is, a certificate which has the same subject and issuer, sometimes called a *root certificate*. The certificates should just be concatenated together in the certificate file. For example, suppose we had a three certificate chain, from our server certificate to the certificate of the certification authority that signed our server certificate, to the root certificate of the agency which issued the certification authority's certificate:

```
-----BEGIN CERTIFICATE-----
... (certificate for your server)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the certificate for the CA)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the root certificate for the CA's issuer)...
-----END CERTIFICATE-----
```

If you are going to require validation of the other side of the connection's certificate, you need to provide a "CA certs" file, filled with the certificate chains for each issuer you are willing to trust. Again, this file just contains these chains concatenated together. For validation, Python will use the first chain it finds in the file which matches.

Some "standard" root certificates are available from various certification authorities: [CACert.org](#), [Thawte](#), [Verisign](#), [Positive SSL](#) (used by python.org), [Equifax](#) and [GeoTrust](#).

In general, if you are using SSL3 or TLS1, you don't need to put the full chain in your "CA certs" file; you only need the root certificates, and the remote peer is supposed to furnish the other certificates necessary to chain from its certificate to a root certificate. See [RFC 4158](#) for more discussion of the way in which certification chains can be built.

If you are going to create a server that provides SSL-encrypted connection services, you will need to acquire a certificate for that service. There are many ways of acquiring appropriate certificates, such as buying one from a certification authority. Another common practice is to generate a self-signed certificate. The simplest way to do this is with the OpenSSL package, using something like the following:

```
% openssl req -new -x509 -days 365 -nodes -out cert.pem -keyout cert.pem
Generating a 1024 bit RSA private key
.....++++++
.....++++++
```

```
writing new private key to 'cert.pem'
```

```
-----
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN.

There are quite a few fields but you can leave some blank

For some fields there will be a default value,

If you enter '.', the field will be left blank.

```
-----
```

```
Country Name (2 letter code) [AU]:US
```

```
State or Province Name (full name) [Some-State]:MyState
```

```
Locality Name (eg, city) []:Some City
```

```
Organization Name (eg, company) [Internet Widgits Pty Ltd]:My Organization, Inc.
```

```
Organizational Unit Name (eg, section) []:My Group
```

```
Common Name (eg, YOUR name) []:myserver.mygroup.myorganization.com
```

```
Email Address []:ops@myserver.mygroup.myorganization.com
```

```
%
```

The disadvantage of a self-signed certificate is that it is its own root certificate, and no one else will have it in their cache of known (and trusted) root certificates.

### 17.3.4 Examples

#### Testing for SSL support

To test for the presence of SSL support in a Python installation, user code should use the following idiom:

```
try:
    import ssl
except ImportError:
    pass
else:
    ... # do something that requires SSL support
```

#### Client-side operation

This example connects to an SSL server, prints the server's address and certificate, sends some bytes, and reads part of the response:

```
import socket, ssl, pprint

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# require a certificate from the server
ssl_sock = ssl.wrap_socket(s,
                           ca_certs="/etc/ca_certs_file",
                           cert_reqs=ssl.CERT_REQUIRED)

ssl_sock.connect(('www.verisign.com', 443))

print repr(ssl_sock.getpeername())
print ssl_sock.cipher()
print pprint.pformat(ssl_sock.getpeercert())
```

```
# Set a simple HTTP request -- use httplib in actual code.
ssl_sock.write("""GET / HTTP/1.0\r
Host: www.verisign.com\r\n\r\n""")

# Read a chunk of data. Will not necessarily
# read all the data returned by the server.
data = ssl_sock.read()

# note that closing the SSLSocket will also close the underlying socket
ssl_sock.close()
```

As of September 6, 2007, the certificate printed by this program looked like this:

```
{'notAfter': 'May  8 23:59:59 2009 GMT',
 'subject': (('serialNumber', u'2497886'),),
            (('1.3.6.1.4.1.311.60.2.1.3', u'US'),),
            (('1.3.6.1.4.1.311.60.2.1.2', u'Delaware'),),
            (('countryName', u'US'),),
            (('postalCode', u'94043'),),
            (('stateOrProvinceName', u'California'),),
            (('localityName', u'Mountain View'),),
            (('streetAddress', u'487 East Middlefield Road'),),
            (('organizationName', u'VeriSign, Inc.'),),
            (('organizationalUnitName',
             u'Production Security Services'),),
            (('organizationalUnitName',
             u'Terms of use at www.verisign.com/rpa (c)06'),),
            (('commonName', u'www.verisign.com'),)}
```

which is a fairly poorly-formed subject field.

## Server-side operation

For server operation, typically you'd need to have a server certificate, and private key, each in a file. You'd open a socket, bind it to a port, call `listen()` on it, then start waiting for clients to connect:

```
import socket, ssl
```

```
bindsocket = socket.socket()
bindsocket.bind(('myaddr.mydomain.com', 10023))
bindsocket.listen(5)
```

When one did, you'd call `accept()` on the socket to get the new socket from the other end, and use `wrap_socket()` to create a server-side SSL context for it:

```
while True:
    newsocket, fromaddr = bindsocket.accept()
    connstream = ssl.wrap_socket(newsocket,
                                server_side=True,
                                certfile="mycertfile",
                                keyfile="mykeyfile",
                                ssl_version=ssl.PROTOCOL_TLSv1)

    try:
        deal_with_client(connstream)
    finally:
```

```
connstream.shutdown(socket.SHUT_RDWR)
connstream.close()
```

Then you'd read data from the `connstream` and do something with it till you are finished with the client (or the client is finished with you):

```
def deal_with_client(connstream):
    data = connstream.read()
    # null data means the client is finished with us
    while data:
        if not do_something(connstream, data):
            # we'll assume do_something returns False
            # when we're finished with client
            break
        data = connstream.read()
    # finished with client
```

And go back to listening for new client connections.

### See Also:

**Class `socket.socket`** Documentation of underlying `socket` class

**TLS (Transport Layer Security) and SSL (Secure Socket Layer)** Debby Koren

**RFC 1422: Privacy Enhancement for Internet Electronic Mail: Part II: Certificate-Based Key Management**  
Steve Kent

**RFC 1750: Randomness Recommendations for Security** D. Eastlake et. al.

**RFC 3280: Internet X.509 Public Key Infrastructure Certificate and CRL Profile** Housley et. al.

## 17.4 `signal` — Set handlers for asynchronous events

This module provides mechanisms to use signal handlers in Python. Some general rules for working with signals and their handlers:

- A handler for a particular signal, once set, remains installed until it is explicitly reset (Python emulates the BSD style interface regardless of the underlying implementation), with the exception of the handler for `SIGCHLD`, which follows the underlying implementation.
- There is no way to “block” signals temporarily from critical sections (since this is not supported by all Unix flavors).
- Although Python signal handlers are called asynchronously as far as the Python user is concerned, they can only occur between the “atomic” instructions of the Python interpreter. This means that signals arriving during long calculations implemented purely in C (such as regular expression matches on large bodies of text) may be delayed for an arbitrary amount of time.
- When a signal arrives during an I/O operation, it is possible that the I/O operation raises an exception after the signal handler returns. This is dependent on the underlying Unix system's semantics regarding interrupted system calls.
- Because the C signal handler always returns, it makes little sense to catch synchronous errors like `SIGFPE` or `SIGSEGV`.
- Python installs a small number of signal handlers by default: `SIGPIPE` is ignored (so write errors on pipes and sockets can be reported as ordinary Python exceptions) and `SIGINT` is translated into a `KeyboardInterrupt` exception. All of these can be overridden.

- Some care must be taken if both signals and threads are used in the same program. The fundamental thing to remember in using signals and threads simultaneously is: always perform `signal()` operations in the main thread of execution. Any thread can perform an `alarm()`, `getsignal()`, `pause()`, `setitimer()` or `getitimer()`; only the main thread can set a new signal handler, and the main thread will be the only one to receive signals (this is enforced by the Python `signal` module, even if the underlying thread implementation supports sending signals to individual threads). This means that signals can't be used as a means of inter-thread communication. Use locks instead.

The variables defined in the `signal` module are:

`signal.SIG_DFL`

This is one of two standard signal handling options; it will simply perform the default function for the signal. For example, on most systems the default action for `SIGQUIT` is to dump core and exit, while the default action for `SIGCHLD` is to simply ignore it.

`signal.SIG_IGN`

This is another standard signal handler, which will simply ignore the given signal.

**SIG\***

All the signal numbers are defined symbolically. For example, the hangup signal is defined as `signal.SIGHUP`; the variable names are identical to the names used in C programs, as found in `<signal.h>`. The Unix man page for `'signal()'` lists the existing signals (on some systems this is `signal(2)`, on others the list is in `signal(7)`). Note that not all systems define the same set of signal names; only those names defined by the system are defined by this module.

`signal.CTRL_C_EVENT`

The signal corresponding to the CTRL+C keystroke event. This signal can only be used with `os.kill()`.

Availability: Windows. New in version 2.7.

`signal.CTRL_BREAK_EVENT`

The signal corresponding to the CTRL+BREAK keystroke event. This signal can only be used with `os.kill()`.

Availability: Windows. New in version 2.7.

`signal.NSIG`

One more than the number of the highest signal number.

`signal.ITIMER_REAL`

Decrements interval timer in real time, and delivers `SIGALRM` upon expiration.

`signal.ITIMER_VIRTUAL`

Decrements interval timer only when the process is executing, and delivers `SIGVTALRM` upon expiration.

`signal.ITIMER_PROF`

Decrements interval timer both when the process executes and when the system is executing on behalf of the process. Coupled with `ITIMER_VIRTUAL`, this timer is usually used to profile the time spent by the application in user and kernel space. `SIGPROF` is delivered upon expiration.

The `signal` module defines one exception:

**exception** `signal.ItimerError`

Raised to signal an error from the underlying `setitimer()` or `getitimer()` implementation. Expect this error if an invalid interval timer or a negative time is passed to `setitimer()`. This error is a subtype of `IOError`.

The `signal` module defines the following functions:

`signal.alarm(time)`

If `time` is non-zero, this function requests that a `SIGALRM` signal be sent to the process in `time` seconds. Any previously scheduled alarm is canceled (only one alarm can be scheduled at any time). The returned value is

then the number of seconds before any previously set alarm was to have been delivered. If *time* is zero, no alarm is scheduled, and any scheduled alarm is canceled. If the return value is zero, no alarm is currently scheduled. (See the Unix man page *alarm(2)*.) Availability: Unix.

`signal.getsignal(signalnum)`

Return the current signal handler for the signal *signalnum*. The returned value may be a callable Python object, or one of the special values `signal.SIG_IGN`, `signal.SIG_DFL` or `None`. Here, `signal.SIG_IGN` means that the signal was previously ignored, `signal.SIG_DFL` means that the default way of handling the signal was previously in use, and `None` means that the previous signal handler was not installed from Python.

`signal.pause()`

Cause the process to sleep until a signal is received; the appropriate handler will then be called. Returns nothing. Not on Windows. (See the Unix man page *signal(2)*.)

`signal.setitimer(which, seconds[, interval])`

Sets given interval timer (one of `signal.ITIMER_REAL`, `signal.ITIMER_VIRTUAL` or `signal.ITIMER_PROF`) specified by *which* to fire after *seconds* (float is accepted, different from `alarm()`) and after that every *interval* seconds. The interval timer specified by *which* can be cleared by setting *seconds* to zero.

When an interval timer fires, a signal is sent to the process. The signal sent is dependent on the timer being used; `signal.ITIMER_REAL` will deliver `SIGALRM`, `signal.ITIMER_VIRTUAL` sends `SIGVTALRM`, and `signal.ITIMER_PROF` will deliver `SIGPROF`.

The old values are returned as a tuple: (delay, interval).

Attempting to pass an invalid interval timer will cause an `ItimerError`. Availability: Unix. New in version 2.6.

`signal.getitimer(which)`

Returns current value of a given interval timer specified by *which*. Availability: Unix. New in version 2.6.

`signal.set_wakeup_fd(fd)`

Set the wakeup fd to *fd*. When a signal is received, a `'\0'` byte is written to the fd. This can be used by a library to wakeup a poll or select call, allowing the signal to be fully processed.

The old wakeup fd is returned. *fd* must be non-blocking. It is up to the library to remove any bytes before calling poll or select again.

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a `ValueError` exception to be raised. New in version 2.6.

`signal.siginterrupt(signalnum, flag)`

Change system call restart behaviour: if *flag* is `False`, system calls will be restarted when interrupted by signal *signalnum*, otherwise system calls will be interrupted. Returns nothing. Availability: Unix (see the man page *siginterrupt(3)* for further information).

Note that installing a signal handler with `signal()` will reset the restart behaviour to interruptible by implicitly calling `siginterrupt()` with a true *flag* value for the given signal. New in version 2.6.

`signal.signal(signalnum, handler)`

Set the handler for signal *signalnum* to the function *handler*. *handler* can be a callable Python object taking two arguments (see below), or one of the special values `signal.SIG_IGN` or `signal.SIG_DFL`. The previous signal handler will be returned (see the description of `getsignal()` above). (See the Unix man page *signal(2)*.)

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a `ValueError` exception to be raised.

The *handler* is called with two arguments: the signal number and the current stack frame (`None` or a frame object; for a description of frame objects, see the *description in the type hierarchy* or see the attribute descriptions

in the `inspect` module).

On Windows, `signal()` can only be called with `SIGABRT`, `SIGFPE`, `SIGILL`, `SIGINT`, `SIGSEGV`, or `SIGTERM`. A `ValueError` will be raised in any other case.

### 17.4.1 Example

Here is a minimal example program. It uses the `alarm()` function to limit the time spent waiting to open a file; this is useful if the file is for a serial device that may not be turned on, which would normally cause the `os.open()` to hang indefinitely. The solution is to set a 5-second alarm before opening the file; if the operation takes too long, the alarm signal will be sent, and the handler raises an exception.

```
import signal, os

def handler(signum, frame):
    print 'Signal handler called with signal', signum
    raise IOError("Couldn't open device!")

# Set the signal handler and a 5-second alarm
signal.signal(signal.SIGALRM, handler)
signal.alarm(5)

# This open() may hang indefinitely
fd = os.open('/dev/ttyS0', os.O_RDWR)

signal.alarm(0)          # Disable the alarm
```

## 17.5 popen2 — Subprocesses with accessible I/O streams

Deprecated since version 2.6: This module is obsolete. Use the `subprocess` module. Check especially the *Replacing Older Functions with the subprocess Module* section. This module allows you to spawn processes and connect to their input/output/error pipes and obtain their return codes under Unix and Windows.

The `subprocess` module provides more powerful facilities for spawning new processes and retrieving their results. Using the `subprocess` module is preferable to using the `popen2` module.

The primary interface offered by this module is a trio of factory functions. For each of these, if `bufsize` is specified, it specifies the buffer size for the I/O pipes. `mode`, if provided, should be the string `'b'` or `'t'`; on Windows this is needed to determine whether the file objects should be opened in binary or text mode. The default value for `mode` is `'t'`.

On Unix, `cmd` may be a sequence, in which case arguments will be passed directly to the program without shell intervention (as with `os.spawnv()`). If `cmd` is a string it will be passed to the shell (as with `os.system()`).

The only way to retrieve the return codes for the child processes is by using the `poll()` or `wait()` methods on the `Popen3` and `Popen4` classes; these are only available on Unix. This information is not available when using the `popen2()`, `popen3()`, and `popen4()` functions, or the equivalent functions in the `os` module. (Note that the tuples returned by the `os` module's functions are in a different order from the ones returned by the `popen2` module.)

```
popen2.popen2(cmd[, bufsize[, mode]])
```

Executes `cmd` as a sub-process. Returns the file objects (`child_stdout`, `child_stdin`).

```
popen2.popen3(cmd[, bufsize[, mode]])
```

Executes `cmd` as a sub-process. Returns the file objects (`child_stdout`, `child_stdin`, `child_stderr`).

`popen2.Popen4(cmd[, bufsize[, mode]])`  
Executes *cmd* as a sub-process. Returns the file objects (`child_stdout_and_stderr`, `child_stdin`). New in version 2.0.

On Unix, a class defining the objects returned by the factory functions is also available. These are not used for the Windows implementation, and are not available on that platform.

**class** `popen2.Popen3(cmd[, capturestderr[, bufsize]])`  
This class represents a child process. Normally, `Popen3` instances are created using the `popen2()` and `popen3()` factory functions described above.

If not using one of the helper functions to create `Popen3` objects, the parameter *cmd* is the shell command to execute in a sub-process. The *capturestderr* flag, if true, specifies that the object should capture standard error output of the child process. The default is false. If the *bufsize* parameter is specified, it specifies the size of the I/O buffers to/from the child process.

**class** `popen2.Popen4(cmd[, bufsize])`  
Similar to `Popen3`, but always captures standard error into the same file object as standard output. These are typically created using `popen4()`. New in version 2.0.

### 17.5.1 Popen3 and Popen4 Objects

Instances of the `Popen3` and `Popen4` classes have the following methods:

`Popen3.poll()`  
Returns `-1` if child process hasn't completed yet, or its status code (see `wait()`) otherwise.

`Popen3.wait()`  
Waits for and returns the status code of the child process. The status code encodes both the return code of the process and information about whether it exited using the `exit()` system call or died due to a signal. Functions to help interpret the status code are defined in the `os` module; see section *Process Management* for the `W*` family of functions.

The following attributes are also available:

`Popen3.fromchild`  
A file object that provides output from the child process. For `Popen4` instances, this will provide both the standard output and standard error streams.

`Popen3.tochild`  
A file object that provides input to the child process.

`Popen3.childerr`  
A file object that provides error output from the child process, if *capturestderr* was true for the constructor, otherwise `None`. This will always be `None` for `Popen4` instances.

`Popen3.pid`  
The process ID of the child process.

### 17.5.2 Flow Control Issues

Any time you are working with any form of inter-process communication, control flow needs to be carefully thought out. This remains the case with the file objects provided by this module (or the `os` module equivalents).

When reading output from a child process that writes a lot of data to standard error while the parent is reading from the child's standard output, a deadlock can occur. A similar situation can occur with other combinations of reads and writes. The essential factors are that more than `_PC_PIPE_BUF` bytes are being written by one process in a blocking fashion, while the other process is reading from the first process, also in a blocking fashion.

There are several ways to deal with this situation.

The simplest application change, in many cases, will be to follow this model in the parent process:

```
import popen2
```

```
r, w, e = popen2.popen3('python slave.py')
e.readlines()
r.readlines()
r.close()
e.close()
w.close()
```

with code like this in the child:

```
import os
import sys
```

```
# note that each of these print statements
# writes a single long string
```

```
print >>sys.stderr, 400 * 'this is a test\n'
os.close(sys.stderr.fileno())
print >>sys.stdout, 400 * 'this is another test\n'
```

In particular, note that `sys.stderr` must be closed after writing all data, or `readlines()` won't return. Also note that `os.close()` must be used, as `sys.stderr.close()` won't close `stderr` (otherwise assigning to `sys.stderr` will silently close it, so no further errors can be printed).

Applications which need to support a more general approach should integrate I/O over pipes with their `select()` loops, or use separate threads to read each of the individual files provided by whichever `popen*()` function or `Popen*` class was used.

#### See Also:

**Module `subprocess`** Module for spawning and managing subprocesses.

## 17.6 `asyncore` — Asynchronous socket handler

**Source code:** `Lib/asyncore.py`

This module provides the basic infrastructure for writing asynchronous socket service clients and servers.

There are only two ways to have a program on a single processor do “more than one thing at a time.” Multi-threaded programming is the simplest and most popular way to do it, but there is another very different technique, that lets you have nearly all the advantages of multi-threading, without actually using multiple threads. It's really only practical if your program is largely I/O bound. If your program is processor bound, then pre-emptive scheduled threads are probably what you really need. Network servers are rarely processor bound, however.

If your operating system supports the `select()` system call in its I/O library (and nearly all do), then you can use it to juggle multiple communication channels at once; doing other work while your I/O is taking place in the “background.” Although this strategy can seem strange and complex, especially at first, it is in many ways easier to understand and control than multi-threaded programming. The `asyncore` module solves many of the difficult problems for you, making the task of building sophisticated high-performance network servers and clients a snap. For “conversational” applications and protocols the companion `asynchat` module is invaluable.

The basic idea behind both modules is to create one or more network *channels*, instances of class `asyncore.dispatcher` and `asynchat.async_chat`. Creating the channels adds them to a global map, used by the `loop()` function if you do not provide it with your own *map*.

Once the initial channel(s) is(are) created, calling the `loop()` function activates channel service, which continues until the last channel (including any that have been added to the map during asynchronous service) is closed.

`asyncore.loop([timeout[, use_poll[, map[, count]]]])`

Enter a polling loop that terminates after *count* passes or all open channels have been closed. All arguments are optional. The *count* parameter defaults to `None`, resulting in the loop terminating only when all channels have been closed. The *timeout* argument sets the timeout parameter for the appropriate `select()` or `poll()` call, measured in seconds; the default is 30 seconds. The *use\_poll* parameter, if true, indicates that `poll()` should be used in preference to `select()` (the default is `False`).

The *map* parameter is a dictionary whose items are the channels to watch. As channels are closed they are deleted from their map. If *map* is omitted, a global map is used. Channels (instances of `asyncore.dispatcher`, `asynchat.async_chat` and subclasses thereof) can freely be mixed in the map.

**class `asyncore.dispatcher`**

The `dispatcher` class is a thin wrapper around a low-level socket object. To make it more useful, it has a few methods for event-handling which are called from the asynchronous loop. Otherwise, it can be treated as a normal non-blocking socket object.

The firing of low-level events at certain times or in certain connection states tells the asynchronous loop that certain higher-level events have taken place. For example, if we have asked for a socket to connect to another host, we know that the connection has been made when the socket becomes writable for the first time (at this point you know that you may write to it with the expectation of success). The implied higher-level events are:

Event	Description
<code>handle_connect()</code>	Implied by the first read or write event
<code>handle_close()</code>	Implied by a read event with no data available
<code>handle_accept()</code>	Implied by a read event on a listening socket

During asynchronous processing, each mapped channel's `readable()` and `writable()` methods are used to determine whether the channel's socket should be added to the list of channels `select()`ed or `poll()`ed for read and write events.

Thus, the set of channel events is larger than the basic socket events. The full set of methods that can be overridden in your subclass follows:

**`handle_read()`**

Called when the asynchronous loop detects that a `read()` call on the channel's socket will succeed.

**`handle_write()`**

Called when the asynchronous loop detects that a writable socket can be written. Often this method will implement the necessary buffering for performance. For example:

```
def handle_write(self):
    sent = self.send(self.buffer)
    self.buffer = self.buffer[sent:]
```

**`handle_expt()`**

Called when there is out of band (OOB) data for a socket connection. This will almost never happen, as OOB is tenuously supported and rarely used.

**`handle_connect()`**

Called when the active opener's socket actually makes a connection. Might send a "welcome" banner, or initiate a protocol negotiation with the remote endpoint, for example.

**handle\_close()**

Called when the socket is closed.

**handle\_error()**

Called when an exception is raised and not otherwise handled. The default version prints a condensed traceback.

**handle\_accept()**

Called on listening channels (passive openers) when a connection can be established with a new remote endpoint that has issued a `connect()` call for the local endpoint.

**readable()**

Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which read events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in read events.

**writable()**

Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which write events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in write events.

In addition, each channel delegates or extends many of the socket methods. Most of these are nearly identical to their socket partners.

**create\_socket(*family, type*)**

This is identical to the creation of a normal socket, and will use the same options for creation. Refer to the `socket` documentation for information on creating sockets.

**connect(*address*)**

As with the normal socket object, *address* is a tuple with the first element the host to connect to, and the second the port number.

**send(*data*)**

Send *data* to the remote end-point of the socket.

**recv(*buffer\_size*)**

Read at most *buffer\_size* bytes from the socket's remote end-point. An empty string implies that the channel has been closed from the other end.

**listen(*backlog*)**

Listen for connections made to the socket. The *backlog* argument specifies the maximum number of queued connections and should be at least 1; the maximum value is system-dependent (usually 5).

**bind(*address*)**

Bind the socket to *address*. The socket must not already be bound. (The format of *address* depends on the address family — refer to the `socket` documentation for more information.) To mark the socket as re-usable (setting the `SO_REUSEADDR` option), call the `dispatcher` object's `set_reuse_addr()` method.

**accept()**

Accept a connection. The socket must be bound to an address and listening for connections. The return value can be either `None` or a pair (*conn*, *address*) where *conn* is a *new* socket object usable to send and receive data on the connection, and *address* is the address bound to the socket on the other end of the connection. When `None` is returned it means the connection didn't take place, in which case the server should just ignore this event and keep listening for further incoming connections.

**close()**

Close the socket. All future operations on the socket object will fail. The remote end-point will receive no more data (after queued data is flushed). Sockets are automatically closed when they are garbage-collected.

### **class** `asyncore.dispatcher_with_send`

A `dispatcher` subclass which adds simple buffered output capability, useful for simple clients. For more sophisticated usage use `asynchat.async_chat`.

### **class** `asyncore.file_dispatcher`

A `file_dispatcher` takes a file descriptor or file object along with an optional map argument and wraps it for use with the `poll()` or `loop()` functions. If provided a file object or anything with a `fileno()` method, that method will be called and passed to the `file_wrapper` constructor. Availability: UNIX.

### **class** `asyncore.file_wrapper`

A `file_wrapper` takes an integer file descriptor and calls `os.dup()` to duplicate the handle so that the original handle may be closed independently of the `file_wrapper`. This class implements sufficient methods to emulate a socket for use by the `file_dispatcher` class. Availability: UNIX.

## 17.6.1 `asyncore` Example basic HTTP client

Here is a very basic HTTP client that uses the `dispatcher` class to implement its socket handling:

```
import asyncore, socket

class HTTPClient(asyncore.dispatcher):

    def __init__(self, host, path):
        asyncore.dispatcher.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.connect((host, 80))
        self.buffer = 'GET %s HTTP/1.0\r\n\r\n' % path

    def handle_connect(self):
        pass

    def handle_close(self):
        self.close()

    def handle_read(self):
        print self.recv(8192)

    def writable(self):
        return len(self.buffer) > 0

    def handle_write(self):
        sent = self.send(self.buffer)
        self.buffer = self.buffer[sent:]

client = HTTPClient('www.python.org', '/')
asyncore.loop()
```

## 17.6.2 `asyncore` Example basic echo server

Here is a basic echo server that uses the `dispatcher` class to accept connections and dispatches the incoming connections to a handler:

```

import asyncio
import socket

class EchoHandler(asyncio.dispatcher_with_send):

    def handle_read(self):
        data = self.recv(8192)
        if data:
            self.send(data)

class EchoServer(asyncio.dispatcher):

    def __init__(self, host, port):
        asyncio.dispatcher.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.set_reuse_addr()
        self.bind((host, port))
        self.listen(5)

    def handle_accept(self):
        pair = self.accept()
        if pair is None:
            pass
        else:
            sock, addr = pair
            print 'Incoming connection from %s' % repr(addr)
            handler = EchoHandler(sock)

server = EchoServer('localhost', 8080)
asyncio.loop()

```

## 17.7 `asyncchat` — Asynchronous socket command/response handler

**Source code:** `Lib/asyncchat.py`

This module builds on the `asyncio` infrastructure, simplifying asynchronous clients and servers and making it easier to handle protocols whose elements are terminated by arbitrary strings, or are of variable length. `asyncchat` defines the abstract class `async_chat` that you subclass, providing implementations of the `collect_incoming_data()` and `found_terminator()` methods. It uses the same asynchronous loop as `asyncio`, and the two types of channel, `asyncio.dispatcher` and `asyncchat.async_chat`, can freely be mixed in the channel map. Typically an `asyncio.dispatcher` server channel generates new `asyncchat.async_chat` channel objects as it receives incoming connection requests.

### **class** `asyncchat.async_chat`

This class is an abstract subclass of `asyncio.dispatcher`. To make practical use of the code you must subclass `async_chat`, providing meaningful `collect_incoming_data()` and `found_terminator()` methods. The `asyncio.dispatcher` methods can be used, although not all make sense in a message/response context.

Like `asyncio.dispatcher`, `async_chat` defines a set of events that are generated by an analysis of socket conditions after a `select()` call. Once the polling loop has been started the `async_chat` object's methods are called by the event-processing framework with no action on the part of the programmer.

Two class attributes can be modified, to improve performance, or possibly even to conserve memory.

**ac\_in\_buffer\_size**

The asynchronous input buffer size (default 4096).

**ac\_out\_buffer\_size**

The asynchronous output buffer size (default 4096).

Unlike `asyncore.dispatcher`, `async_chat` allows you to define a first-in-first-out queue (fifo) of *producers*. A producer need have only one method, `more()`, which should return data to be transmitted on the channel. The producer indicates exhaustion (*i.e.* that it contains no more data) by having its `more()` method return the empty string. At this point the `async_chat` object removes the producer from the fifo and starts using the next producer, if any. When the producer fifo is empty the `handle_write()` method does nothing. You use the channel object's `set_terminator()` method to describe how to recognize the end of, or an important breakpoint in, an incoming transmission from the remote endpoint.

To build a functioning `async_chat` subclass your input methods `collect_incoming_data()` and `found_terminator()` must handle the data that the channel receives asynchronously. The methods are described below.

`async_chat.close_when_done()`

Pushes a `None` on to the producer fifo. When this producer is popped off the fifo it causes the channel to be closed.

`async_chat.collect_incoming_data(data)`

Called with `data` holding an arbitrary amount of received data. The default method, which must be overridden, raises a `NotImplementedError` exception.

`async_chat.discard_buffers()`

In emergencies this method will discard any data held in the input and/or output buffers and the producer fifo.

`async_chat.found_terminator()`

Called when the incoming data stream matches the termination condition set by `set_terminator()`. The default method, which must be overridden, raises a `NotImplementedError` exception. The buffered input data should be available via an instance attribute.

`async_chat.get_terminator()`

Returns the current terminator for the channel.

`async_chat.push(data)`

Pushes data on to the channel's fifo to ensure its transmission. This is all you need to do to have the channel write the data out to the network, although it is possible to use your own producers in more complex schemes to implement encryption and chunking, for example.

`async_chat.push_with_producer(producer)`

Takes a producer object and adds it to the producer fifo associated with the channel. When all currently-pushed producers have been exhausted the channel will consume this producer's data by calling its `more()` method and send the data to the remote endpoint.

`async_chat.set_terminator(term)`

Sets the terminating condition to be recognized on the channel. `term` may be any of three types of value, corresponding to three different ways to handle incoming protocol data.

term	Description
<i>string</i>	Will call <code>found_terminator()</code> when the string is found in the input stream
<i>integer</i>	Will call <code>found_terminator()</code> when the indicated number of characters have been received
<code>None</code>	The channel continues to collect data forever

Note that any data following the terminator will be available for reading by the channel after `found_terminator()` is called.

## 17.7.1 `asyncchat` - Auxiliary Classes

**class** `asyncchat.fifo` (`[list=None]`)

A `fifo` holding data which has been pushed by the application but not yet popped for writing to the channel. A `fifo` is a list used to hold data and/or producers until they are required. If the `list` argument is provided then it should contain producers or data items to be written to the channel.

**is\_empty** ()

Returns `True` if and only if the `fifo` is empty.

**first** ()

Returns the least-recently `push` () ed item from the `fifo`.

**push** (`data`)

Adds the given data (which may be a string or a producer object) to the producer `fifo`.

**pop** ()

If the `fifo` is not empty, returns `True`, `first` (), deleting the popped item. Returns `False`, `None` for an empty `fifo`.

## 17.7.2 `asyncchat` Example

The following partial example shows how HTTP requests can be read with `async_chat`. A web server might create an `http_request_handler` object for each incoming client connection. Notice that initially the channel terminator is set to match the blank line at the end of the HTTP headers, and a flag indicates that the headers are being read.

Once the headers have been read, if the request is of type POST (indicating that further data are present in the input stream) then the `Content-Length`: header is used to set a numeric terminator to read the right amount of data from the channel.

The `handle_request` () method is called once all relevant input has been marshalled, after setting the channel terminator to `None` to ensure that any extraneous data sent by the web client are ignored.

```
class http_request_handler (asyncchat.async_chat):

    def __init__ (self, sock, addr, sessions, log):
        asyncchat.async_chat.__init__ (self, sock=sock)
        self.addr = addr
        self.sessions = sessions
        self.ibuffer = []
        self.obuffer = ""
        self.set_terminator ("\r\n\r\n")
        self.reading_headers = True
        self.handling = False
        self.cgi_data = None
        self.log = log

    def collect_incoming_data (self, data):
        """Buffer the data"""
        self.ibuffer.append (data)

    def found_terminator (self):
        if self.reading_headers:
            self.reading_headers = False
            self.parse_headers ("".join(self.ibuffer))
```

```
self.ibuffer = []
if self.op.upper() == "POST":
    clen = self.headers.getheader("content-length")
    self.set_terminator(int(clen))
else:
    self.handling = True
    self.set_terminator(None)
    self.handle_request()
elif not self.handling:
    self.set_terminator(None) # browsers sometimes over-send
    self.cgi_data = parse(self.headers, "".join(self.ibuffer))
    self.handling = True
    self.ibuffer = []
    self.handle_request()
```

# INTERNET DATA HANDLING

This chapter describes modules which support handling data formats commonly used on the Internet.

## 18.1 `email` — An email and MIME handling package

New in version 2.2. The `email` package is a library for managing email messages, including MIME and other **RFC 2822**-based message documents. It subsumes most of the functionality in several older standard modules such as `rfc822`, `mimetools`, `multifile`, and other non-standard packages such as `mimencntl`. It is specifically *not* designed to do any sending of email messages to SMTP (**RFC 2821**), NNTP, or other servers; those are functions of modules such as `smtplib` and `nntplib`. The `email` package attempts to be as RFC-compliant as possible, supporting in addition to

**RFC 2822**, such MIME-related RFCs as **RFC 2045**, **RFC 2046**, **RFC 2047**, and **RFC 2231**.

The primary distinguishing feature of the `email` package is that it splits the parsing and generating of email messages from the internal *object model* representation of email. Applications using the `email` package deal primarily with objects; you can add sub-objects to messages, remove sub-objects from messages, completely re-arrange the contents, etc. There is a separate parser and a separate generator which handles the transformation from flat text to the object model, and then back to flat text again. There are also handy subclasses for some common MIME object types, and a few miscellaneous utilities that help with such common tasks as extracting and parsing message field values, creating RFC-compliant dates, etc.

The following sections describe the functionality of the `email` package. The ordering follows a progression that should be common in applications: an email message is read as flat text from a file or other source, the text is parsed to produce the object structure of the email message, this structure is manipulated, and finally, the object tree is rendered back into flat text.

It is perfectly feasible to create the object structure out of whole cloth — i.e. completely from scratch. From there, a similar progression can be taken as above.

Also included are detailed specifications of all the classes and modules that the `email` package provides, the exception classes you might encounter while using the `email` package, some auxiliary utilities, and a few examples. For users of the older `mimelib` package, or previous versions of the `email` package, a section on differences and porting is provided.

Contents of the `email` package documentation:

### 18.1.1 `email.message`: Representing an email message

The central class in the `email` package is the `Message` class, imported from the `email.message` module. It is the base class for the `email` object model. `Message` provides the core functionality for setting and querying header fields, and for accessing message bodies.

Conceptually, a `Message` object consists of *headers* and *payloads*. Headers are **RFC 2822** style field names and values where the field name and value are separated by a colon. The colon is not part of either the field name or the field value.

Headers are stored and returned in case-preserving form but are matched case-insensitively. There may also be a single envelope header, also known as the *Unix-From* header or the `From_` header. The payload is either a string in the case of simple message objects or a list of `Message` objects for MIME container documents (e.g. *multipart/\** and *message/rfc822*).

`Message` objects provide a mapping style interface for accessing the message headers, and an explicit interface for accessing both the headers and the payload. It provides convenience methods for generating a flat text representation of the message object tree, for accessing commonly used header parameters, and for recursively walking over the object tree.

Here are the methods of the `Message` class:

**class** `email.message.Message`

The constructor takes no arguments.

**as\_string** (`[unixfrom]`)

Return the entire message flattened as a string. When optional `unixfrom` is `True`, the envelope header is included in the returned string. `unixfrom` defaults to `False`. Flattening the message may trigger changes to the `Message` if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not always format the message the way you want. For example, by default it mangles lines that begin with `From`. For more flexibility, instantiate a `Generator` instance and use its `flatten()` method directly. For example:

```
from cStringIO import StringIO
from email.generator import Generator
fp = StringIO()
g = Generator(fp, mangle_from_=False, maxheaderlen=60)
g.flatten(msg)
text = fp.getvalue()
```

**\_\_str\_\_** ()

Equivalent to `as_string(unixfrom=True)`.

**is\_multipart** ()

Return `True` if the message's payload is a list of sub-`Message` objects, otherwise return `False`. When `is_multipart()` returns `False`, the payload should be a string object.

**set\_unixfrom** (`unixfrom`)

Set the message's envelope header to `unixfrom`, which should be a string.

**get\_unixfrom** ()

Return the message's envelope header. Defaults to `None` if the envelope header was never set.

**attach** (`payload`)

Add the given `payload` to the current payload, which must be `None` or a list of `Message` objects before the call. After the call, the payload will always be a list of `Message` objects. If you want to set the payload to a scalar object (e.g. a string), use `set_payload()` instead.

**get\_payload** (`[i[, decode]]`)

Return the current payload, which will be a list of `Message` objects when `is_multipart()` is `True`, or a string when `is_multipart()` is `False`. If the payload is a list and you mutate the list object, you modify the message's payload in place.

With optional argument *i*, `get_payload()` will return the *i*-th element of the payload, counting from zero, if `is_multipart()` is True. An `IndexError` will be raised if *i* is less than 0 or greater than or equal to the number of items in the payload. If the payload is a string (i.e. `is_multipart()` is False) and *i* is given, a `TypeError` is raised.

Optional *decode* is a flag indicating whether the payload should be decoded or not, according to the *Content-Transfer-Encoding* header. When True and the message is not a multipart, the payload will be decoded if this header's value is `quoted-printable` or `base64`. If some other encoding is used, or *Content-Transfer-Encoding* header is missing, or if the payload has bogus base64 data, the payload is returned as-is (undecoded). If the message is a multipart and the *decode* flag is True, then None is returned. The default for *decode* is False.

**set\_payload**(*payload*[, *charset*])

Set the entire message object's payload to *payload*. It is the client's responsibility to ensure the payload invariants. Optional *charset* sets the message's default character set; see `set_charset()` for details. Changed in version 2.2.2: *charset* argument added.

**set\_charset**(*charset*)

Set the character set of the payload to *charset*, which can either be a `Charset` instance (see `email.charset`), a string naming a character set, or None. If it is a string, it will be converted to a `Charset` instance. If *charset* is None, the *charset* parameter will be removed from the *Content-Type* header (the message will not be otherwise modified). Anything else will generate a `TypeError`.

If there is no existing *MIME-Version* header one will be added. If there is no existing *Content-Type* header, one will be added with a value of `text/plain`. Whether the *Content-Type* header already exists or not, its *charset* parameter will be set to `charset.output_charset`. If `charset.input_charset` and `charset.output_charset` differ, the payload will be re-encoded to the `output_charset`. If there is no existing *Content-Transfer-Encoding* header, then the payload will be transfer-encoded, if needed, using the specified `Charset`, and a header with the appropriate value will be added. If a *Content-Transfer-Encoding* header already exists, the payload is assumed to already be correctly encoded using that *Content-Transfer-Encoding* and is not modified.

The message will be assumed to be of type `text/*`, with the payload either in unicode or encoded with `charset.input_charset`. It will be encoded or converted to `charset.output_charset` and transfer encoded properly, if needed, when generating the plain text representation of the message. MIME headers (*MIME-Version*, *Content-Type*, *Content-Transfer-Encoding*) will be added as needed. New in version 2.2.2.

**get\_charset**()

Return the `Charset` instance associated with the message's payload. New in version 2.2.2.

The following methods implement a mapping-like interface for accessing the message's **RFC 2822** headers. Note that there are some semantic differences between these methods and a normal mapping (i.e. dictionary) interface. For example, in a dictionary there are no duplicate keys, but here there may be duplicate message headers. Also, in dictionaries there is no guaranteed order to the keys returned by `keys()`, but in a `Message` object, headers are always returned in the order they appeared in the original message, or were added to the message later. Any header deleted and then re-added are always appended to the end of the header list.

These semantic differences are intentional and are biased toward maximal convenience.

Note that in all cases, any envelope header present in the message is not included in the mapping interface.

**\_\_len\_\_**()

Return the total number of headers, including duplicates.

**\_\_contains\_\_**(*name*)

Return true if the message object has a field named *name*. Matching is done case-insensitively and *name* should not include the trailing colon. Used for the `in` operator, e.g.:

```
if 'message-id' in myMessage:
    print 'Message-ID:', myMessage['message-id']
```

**\_\_getitem\_\_** (*name*)

Return the value of the named header field. *name* should not include the colon field separator. If the header is missing, `None` is returned; a `KeyError` is never raised.

Note that if the named field appears more than once in the message's headers, exactly which of those field values will be returned is undefined. Use the `get_all()` method to get the values of all the extant named headers.

**\_\_setitem\_\_** (*name, val*)

Add a header to the message with field name *name* and value *val*. The field is appended to the end of the message's existing fields.

Note that this does *not* overwrite or delete any existing header with the same name. If you want to ensure that the new header is the only one present in the message with field name *name*, delete the field first, e.g.:

```
del msg['subject']
msg['subject'] = 'Python roolz!'
```

**\_\_delitem\_\_** (*name*)

Delete all occurrences of the field with name *name* from the message's headers. No exception is raised if the named field isn't present in the headers.

**has\_key** (*name*)

Return true if the message contains a header field named *name*, otherwise return false.

**keys** ()

Return a list of all the message's header field names.

**values** ()

Return a list of all the message's field values.

**items** ()

Return a list of 2-tuples containing all the message's field headers and values.

**get** (*name* [, *failobj*])

Return the value of the named header field. This is identical to `__getitem__()` except that optional *failobj* is returned if the named header is missing (defaults to `None`).

Here are some additional useful methods:

**get\_all** (*name* [, *failobj*])

Return a list of all the values for the field named *name*. If there are no such named headers in the message, *failobj* is returned (defaults to `None`).

**add\_header** (*\_name, \_value, \*\*\_params*)

Extended header setting. This method is similar to `__setitem__()` except that additional header parameters can be provided as keyword arguments. *\_name* is the header field to add and *\_value* is the *primary* value for the header.

For each item in the keyword argument dictionary *\_params*, the key is taken as the parameter name, with underscores converted to dashes (since dashes are illegal in Python identifiers). Normally, the parameter will be added as `key="value"` unless the value is `None`, in which case only the key will be added. If the value contains non-ASCII characters, it must be specified as a three tuple in the format `(CHARSET, LANGUAGE, VALUE)`, where `CHARSET` is a string naming the charset to be used to encode the value, `LANGUAGE` can usually be set to `None` or the empty string (see [RFC 2231](#) for other possibilities), and `VALUE` is the string value containing non-ASCII code points.

Here's an example:

```
msg.add_header('Content-Disposition', 'attachment', filename='bud.gif')
```

This will add a header that looks like

```
Content-Disposition: attachment; filename="bud.gif"
```

An example with non-ASCII characters:

```
msg.add_header('Content-Disposition', 'attachment',
              filename=('iso-8859-1', '', 'Fußballer.ppt'))
```

Which produces

```
Content-Disposition: attachment; filename*="iso-8859-1'Fu%DFballer.ppt"
```

#### **replace\_header** (*\_name*, *\_value*)

Replace a header. Replace the first header found in the message that matches *\_name*, retaining header order and field name case. If no matching header was found, a `KeyError` is raised. New in version 2.2.2.

#### **get\_content\_type** ()

Return the message's content type. The returned string is coerced to lower case of the form *maintype/subtype*. If there was no *Content-Type* header in the message the default type as given by `get_default_type()` will be returned. Since according to

**RFC 2045**, messages always have a default type, `get_content_type()` will always return a value.

**RFC 2045** defines a message's default type to be *text/plain* unless it appears inside a *multipart/digest* container, in which case it would be *message/rfc822*. If the *Content-Type* header has an invalid type specification,

**RFC 2045** mandates that the default type be *text/plain*. New in version 2.2.2.

#### **get\_content\_maintype** ()

Return the message's main content type. This is the *maintype* part of the string returned by `get_content_type()`. New in version 2.2.2.

#### **get\_content\_subtype** ()

Return the message's sub-content type. This is the *subtype* part of the string returned by `get_content_type()`. New in version 2.2.2.

#### **get\_default\_type** ()

Return the default content type. Most messages have a default content type of *text/plain*, except for messages that are subparts of *multipart/digest* containers. Such subparts have a default content type of *message/rfc822*. New in version 2.2.2.

#### **set\_default\_type** (*ctype*)

Set the default content type. *ctype* should either be *text/plain* or *message/rfc822*, although this is not enforced. The default content type is not stored in the *Content-Type* header. New in version 2.2.2.

#### **get\_params** ([*failobj* [, *header* [, *unquote* ]]])

Return the message's *Content-Type* parameters, as a list. The elements of the returned list are 2-tuples of key/value pairs, as split on the '=' sign. The left hand side of the '=' is the key, while the right hand side is the value. If there is no '=' sign in the parameter the value is the empty string, otherwise the value is as described in `get_param()` and is unquoted if optional *unquote* is `True` (the default).

Optional *failobj* is the object to return if there is no *Content-Type* header. Optional *header* is the header to search instead of *Content-Type*. Changed in version 2.2.2: *unquote* argument added.

**get\_param**(*param*[, *failobj*[, *header*[, *unquote* ] ] ])

Return the value of the *Content-Type* header's parameter *param* as a string. If the message has no *Content-Type* header or if there is no such parameter, then *failobj* is returned (defaults to None).

Optional *header* if given, specifies the message header to use instead of *Content-Type*.

Parameter keys are always compared case insensitively. The return value can either be a string, or a 3-tuple if the parameter was **RFC 2231** encoded. When it's a 3-tuple, the elements of the value are of the form (CHARSET, LANGUAGE, VALUE). Note that both CHARSET and LANGUAGE can be None, in which case you should consider VALUE to be encoded in the *us-ascii* charset. You can usually ignore LANGUAGE.

If your application doesn't care whether the parameter was encoded as in

**RFC 2231**, you can collapse the parameter value by calling `email.utils.collapse_rfc2231_value()`, passing in the return value from `get_param()`. This will return a suitably decoded Unicode string when the value is a tuple, or the original string unquoted if it isn't. For example:

```
rawparam = msg.get_param('foo')
param = email.utils.collapse_rfc2231_value(rawparam)
```

In any case, the parameter value (either the returned string, or the VALUE item in the 3-tuple) is always unquoted, unless *unquote* is set to `False`. Changed in version 2.2.2: *unquote* argument added, and 3-tuple return value possible.

**set\_param**(*param*, *value*[, *header*[, *quote*[, *charset*[, *language* ] ] ] ])

Set a parameter in the *Content-Type* header. If the parameter already exists in the header, its value will be replaced with *value*. If the *Content-Type* header has not yet been defined for this message, it will be set to *text/plain* and the new parameter value will be appended as per **RFC 2045**.

Optional *header* specifies an alternative header to *Content-Type*, and all parameters will be quoted as necessary unless optional *quote* is `False` (the default is `True`).

If optional *charset* is specified, the parameter will be encoded according to **RFC 2231**. Optional *language* specifies the RFC 2231 language, defaulting to the empty string. Both *charset* and *language* should be strings. New in version 2.2.2.

**del\_param**(*param*[, *header*[, *quote* ] ])

Remove the given parameter completely from the *Content-Type* header. The header will be re-written in place without the parameter or its value. All values will be quoted as necessary unless *quote* is `False` (the default is `True`). Optional *header* specifies an alternative to *Content-Type*. New in version 2.2.2.

**set\_type**(*type*[, *header*][, *quote*])

Set the main type and subtype for the *Content-Type* header. *type* must be a string in the form *maintype/subtype*, otherwise a `ValueError` is raised.

This method replaces the *Content-Type* header, keeping all the parameters in place. If *quote* is `False`, this leaves the existing header's quoting as is, otherwise the parameters will be quoted (the default).

An alternative header can be specified in the *header* argument. When the *Content-Type* header is set a *MIME-Version* header is also added. New in version 2.2.2.

**get\_filename**([*failobj*])

Return the value of the *filename* parameter of the *Content-Disposition* header of the message. If the header does not have a *filename* parameter, this method falls back to looking for the name

parameter on the *Content-Type* header. If neither is found, or the header is missing, then *failobj* is returned. The returned string will always be unquoted as per `email.utils.unquote()`.

#### `get_boundary ([failobj])`

Return the value of the *boundary* parameter of the *Content-Type* header of the message, or *failobj* if either the header is missing, or has no *boundary* parameter. The returned string will always be unquoted as per `email.utils.unquote()`.

#### `set_boundary (boundary)`

Set the *boundary* parameter of the *Content-Type* header to *boundary*. `set_boundary()` will always quote *boundary* if necessary. A `HeaderParseError` is raised if the message object has no *Content-Type* header.

Note that using this method is subtly different than deleting the old *Content-Type* header and adding a new one with the new *boundary* via `add_header()`, because `set_boundary()` preserves the order of the *Content-Type* header in the list of headers. However, it does *not* preserve any continuation lines which may have been present in the original *Content-Type* header.

#### `get_content_charset ([failobj])`

Return the *charset* parameter of the *Content-Type* header, coerced to lower case. If there is no *Content-Type* header, or if that header has no *charset* parameter, *failobj* is returned.

Note that this method differs from `get_charset()` which returns the `Charset` instance for the default encoding of the message body. New in version 2.2.2.

#### `get_charsets ([failobj])`

Return a list containing the character set names in the message. If the message is a *multipart*, then the list will contain one element for each subpart in the payload, otherwise, it will be a list of length 1.

Each item in the list will be a string which is the value of the *charset* parameter in the *Content-Type* header for the represented subpart. However, if the subpart has no *Content-Type* header, no *charset* parameter, or is not of the *text* main MIME type, then that item in the returned list will be *failobj*.

#### `walk ()`

The `walk()` method is an all-purpose generator which can be used to iterate over all the parts and subparts of a message object tree, in depth-first traversal order. You will typically use `walk()` as the iterator in a `for` loop; each iteration returns the next subpart.

Here's an example that prints the MIME type of every part of a multipart message structure:

```
>>> for part in msg.walk():
...     print part.get_content_type()
multipart/report
text/plain
message/delivery-status
text/plain
text/plain
message/rfc822
```

Changed in version 2.5: The previously deprecated methods `get_type()`, `get_main_type()`, and `get_subtype()` were removed. `Message` objects can also optionally contain two instance attributes, which can be used when generating the plain text of a MIME message.

#### **preamble**

The format of a MIME document allows for some text between the blank line following the headers, and the first multipart boundary string. Normally, this text is never visible in a MIME-aware mail reader because it falls outside the standard MIME armor. However, when viewing the raw text of the message, or when viewing the message in a non-MIME aware reader, this text can become visible.

The *preamble* attribute contains this leading extra-armor text for MIME documents. When the `Parser` discovers some text after the headers but before the first boundary string, it assigns this text to the message's *preamble* attribute. When the `Generator` is writing out the plain text representation of a MIME message, and it finds the message has a *preamble* attribute, it will write this text in the area between the headers and the first boundary. See `email.parser` and `email.generator` for details.

Note that if the message object has no preamble, the *preamble* attribute will be `None`.

### epilogue

The *epilogue* attribute acts the same way as the *preamble* attribute, except that it contains text that appears between the last boundary and the end of the message. Changed in version 2.5: You do not need to set the epilogue to the empty string in order for the `Generator` to print a newline at the end of the file.

### defects

The *defects* attribute contains a list of all the problems found when parsing this message. See `email.errors` for a detailed description of the possible parsing defects. New in version 2.4.

## 18.1.2 `email.parser`: Parsing email messages

Message object structures can be created in one of two ways: they can be created from whole cloth by instantiating `Message` objects and stringing them together via `attach()` and `set_payload()` calls, or they can be created by parsing a flat text representation of the email message.

The `email` package provides a standard parser that understands most email document structures, including MIME documents. You can pass the parser a string or a file object, and the parser will return to you the root `Message` instance of the object structure. For simple, non-MIME messages the payload of this root object will likely be a string containing the text of the message. For MIME messages, the root object will return `True` from its `is_multipart()` method, and the subparts can be accessed via the `get_payload()` and `walk()` methods.

There are actually two parser interfaces available for use, the classic `Parser` API and the incremental `FeedParser` API. The classic `Parser` API is fine if you have the entire text of the message in memory as a string, or if the entire message lives in a file on the file system. `FeedParser` is more appropriate for when you're reading the message from a stream which might block waiting for more input (e.g. reading an email message from a socket). The `FeedParser` can consume and parse the message incrementally, and only returns the root object when you close the parser<sup>1</sup>.

Note that the parser can be extended in limited ways, and of course you can implement your own parser completely from scratch. There is no magical connection between the `email` package's bundled parser and the `Message` class, so your custom parser can create message object trees any way it finds necessary.

### FeedParser API

New in version 2.4. The `FeedParser`, imported from the `email.feedparser` module, provides an API that is conducive to incremental parsing of email messages, such as would be necessary when reading the text of an email message from a source that can block (e.g. a socket). The `FeedParser` can of course be used to parse an email message fully contained in a string or a file, but the classic `Parser` API may be more convenient for such use cases. The semantics and results of the two parser APIs are identical.

The `FeedParser`'s API is simple; you create an instance, feed it a bunch of text until there's no more to feed it, then close the parser to retrieve the root message object. The `FeedParser` is extremely accurate when parsing standards-compliant messages, and it does a very good job of parsing non-compliant messages, providing information about how a message was deemed broken. It will populate a message object's *defects* attribute with a list of any problems it found in a message. See the `email.errors` module for the list of defects that it can find.

Here is the API for the `FeedParser`:

---

<sup>1</sup> As of email package version 3.0, introduced in Python 2.4, the classic `Parser` was re-implemented in terms of the `FeedParser`, so the semantics and results are identical between the two parsers.

**class** `email.parser.FeedParser` (`[_factory]`)

Create a `FeedParser` instance. Optional `_factory` is a no-argument callable that will be called whenever a new message object is needed. It defaults to the `email.message.Message` class.

**feed** (`data`)

Feed the `FeedParser` some more data. `data` should be a string containing one or more lines. The lines can be partial and the `FeedParser` will stitch such partial lines together properly. The lines in the string can have any of the common three line endings, carriage return, newline, or carriage return and newline (they can even be mixed).

**close** ()

Closing a `FeedParser` completes the parsing of all previously fed data, and returns the root message object. It is undefined what happens if you feed more data to a closed `FeedParser`.

## Parser class API

The `Parser` class, imported from the `email.parser` module, provides an API that can be used to parse a message when the complete contents of the message are available in a string or file. The `email.parser` module also provides a second class, called `HeaderParser` which can be used if you're only interested in the headers of the message. `HeaderParser` can be much faster in these situations, since it does not attempt to parse the message body, instead setting the payload to the raw body as a string. `HeaderParser` has the same API as the `Parser` class.

**class** `email.parser.Parser` (`[_class]`)

The constructor for the `Parser` class takes an optional argument `_class`. This must be a callable factory (such as a function or a class), and it is used whenever a sub-message object needs to be created. It defaults to `Message` (see `email.message`). The factory will be called without arguments.

The optional `strict` flag is ignored. Deprecated since version 2.4: Because the `Parser` class is a backward compatible API wrapper around the new-in-Python 2.4 `FeedParser`, *all* parsing is effectively non-strict. You should simply stop passing a `strict` flag to the `Parser` constructor. Changed in version 2.2.2: The `strict` flag was added. Changed in version 2.4: The `strict` flag was deprecated. The other public `Parser` methods are:

**parse** (`fp` [`, headersonly`])

Read all the data from the file-like object `fp`, parse the resulting text, and return the root message object. `fp` must support both the `readline()` and the `read()` methods on file-like objects.

The text contained in `fp` must be formatted as a block of **RFC 2822** style headers and header continuation lines, optionally preceded by an envelope header. The header block is terminated either by the end of the data or by a blank line. Following the header block is the body of the message (which may contain MIME-encoded subparts).

Optional `headersonly` is a flag specifying whether to stop parsing after reading the headers or not. The default is `False`, meaning it parses the entire contents of the file. Changed in version 2.2.2: The `headersonly` flag was added.

**parsestr** (`text` [`, headersonly`])

Similar to the `parse()` method, except it takes a string object instead of a file-like object. Calling this method on a string is exactly equivalent to wrapping `text` in a `StringIO` instance first and calling `parse()`.

Optional `headersonly` is as with the `parse()` method. Changed in version 2.2.2: The `headersonly` flag was added.

Since creating a message object structure from a string or a file object is such a common task, two functions are provided as a convenience. They are available in the top-level `email` package namespace.

`email.message_from_string` (`s` [`, _class` [`, strict`]])

Return a message object structure from a string. This is exactly equivalent to `Parser().parsestr(s)`.

Optional `_class` and `strict` are interpreted as with the `Parser` class constructor. Changed in version 2.2.2: The `strict` flag was added.

```
email.message_from_file(fp[, _class[, strict]])
```

Return a message object structure tree from an open file object. This is exactly equivalent to `Parser().parse(fp)`. Optional `_class` and `strict` are interpreted as with the `Parser` class constructor. Changed in version 2.2.2: The `strict` flag was added.

Here's an example of how you might use this at an interactive Python prompt:

```
>>> import email
>>> msg = email.message_from_string(myString)
```

### Additional notes

Here are some notes on the parsing semantics:

- Most non-*multipart* type messages are parsed as a single message object with a string payload. These objects will return `False` for `is_multipart()`. Their `get_payload()` method will return a string object.
- All *multipart* type messages will be parsed as a container message object with a list of sub-message objects for their payload. The outer container message will return `True` for `is_multipart()` and their `get_payload()` method will return the list of `Message` subparts.
- Most messages with a content type of *message/\** (e.g. *message/delivery-status* and *message/rfc822*) will also be parsed as container object containing a list payload of length 1. Their `is_multipart()` method will return `True`. The single element in the list payload will be a sub-message object.
- Some non-standards compliant messages may not be internally consistent about their *multipart*-edness. Such messages may have a *Content-Type* header of type *multipart*, but their `is_multipart()` method may return `False`. If such messages were parsed with the `FeedParser`, they will have an instance of the `MultipartInvariantViolationDefect` class in their `defects` attribute list. See `email.errors` for details.

### 18.1.3 email.generator: Generating MIME documents

One of the most common tasks is to generate the flat text of the email message represented by a message object structure. You will need to do this if you want to send your message via the `smtplib` module or the `nntplib` module, or print the message on the console. Taking a message object structure and producing a flat text document is the job of the `Generator` class.

Again, as with the `email.parser` module, you aren't limited to the functionality of the bundled generator; you could write one from scratch yourself. However the bundled generator knows how to generate most email in a standards-compliant way, should handle MIME and non-MIME email messages just fine, and is designed so that the transformation from flat text, to a message structure via the `Parser` class, and back to flat text, is idempotent (the input is identical to the output)<sup>2</sup>. On the other hand, using the `Generator` on a `Message` constructed by program may result in changes to the `Message` object as defaults are filled in.

Here are the public methods of the `Generator` class, imported from the `email.generator` module:

```
class email.generator.Generator(outfp[, mangle_from_[, maxheaderlen]])
```

The constructor for the `Generator` class takes a file-like object called `outfp` for an argument. `outfp` must support the `write()` method and be usable as the output file in a Python extended print statement.

---

<sup>2</sup> This statement assumes that you use the appropriate setting for the `unixfrom` argument, and that you set `maxheaderlen=0` (which will preserve whatever the input line lengths were). It is also not strictly true, since in many cases runs of whitespace in headers are collapsed into single blanks. The latter is a bug that will eventually be fixed.

Optional `mangle_from_` is a flag that, when `True`, puts a `>` character in front of any line in the body that starts exactly as `From`, i.e. `From` followed by a space at the beginning of the line. This is the only guaranteed portable way to avoid having such lines be mistaken for a Unix mailbox format envelope header separator (see [WHY THE CONTENT-LENGTH FORMAT IS BAD](#) for details). `mangle_from_` defaults to `True`, but you might want to set this to `False` if you are not writing Unix mailbox format files.

Optional `maxheaderlen` specifies the longest length for a non-continued header. When a header line is longer than `maxheaderlen` (in characters, with tabs expanded to 8 spaces), the header will be split as defined in the `Header` class. Set to zero to disable header wrapping. The default is 78, as recommended (but not required) by [RFC 2822](#).

The other public `Generator` methods are:

**flatten** (*msg* [, *unixfrom* ])

Print the textual representation of the message object structure rooted at *msg* to the output file specified when the `Generator` instance was created. Subparts are visited depth-first and the resulting text will be properly MIME encoded.

Optional `unixfrom` is a flag that forces the printing of the envelope header delimiter before the first [RFC 2822](#) header of the root message object. If the root object has no envelope header, a standard one is crafted. By default, this is set to `False` to inhibit the printing of the envelope delimiter.

Note that for subparts, no envelope header is ever printed. New in version 2.2.2.

**clone** (*fp*)

Return an independent clone of this `Generator` instance with the exact same options. New in version 2.2.2.

**write** (*s*)

Write the string *s* to the underlying file object, i.e. `outfp` passed to `Generator`'s constructor. This provides just enough file-like API for `Generator` instances to be used in extended print statements.

As a convenience, see the methods `Message.as_string()` and `str(aMessage)`, a.k.a. `Message.__str__()`, which simplify the generation of a formatted string representation of a message object. For more detail, see `email.message`.

The `email.generator` module also provides a derived class, called `DecodedGenerator` which is like the `Generator` base class, except that non-`text` parts are substituted with a format string representing the part.

**class** `email.generator.DecodedGenerator` (*outfp* [, *mangle\_from\_* [, *maxheaderlen* [, *fnt* ] ] ])

This class, derived from `Generator` walks through all the subparts of a message. If the subpart is of main type `text`, then it prints the decoded payload of the subpart. Optional `_mangle_from_` and `maxheaderlen` are as with the `Generator` base class.

If the subpart is not of main type `text`, optional `fnt` is a format string that is used instead of the message payload. `fnt` is expanded with the following keywords, `%(keyword)s` format:

- `type` – Full MIME type of the non-`text` part
- `maintype` – Main MIME type of the non-`text` part
- `subtype` – Sub-MIME type of the non-`text` part
- `filename` – Filename of the non-`text` part
- `description` – Description associated with the non-`text` part
- `encoding` – Content transfer encoding of the non-`text` part

The default value for `fnt` is `None`, meaning

```
[Non-text %(type)s part of message omitted, filename %(filename)s]
```

New in version 2.2.2.

Changed in version 2.5: The previously deprecated method `__call__()` was removed.

### 18.1.4 `email.mime`: Creating email and MIME objects from scratch

Ordinarily, you get a message object structure by passing a file or some text to a parser, which parses the text and returns the root message object. However you can also build a complete message structure from scratch, or even individual `Message` objects by hand. In fact, you can also take an existing structure and add new `Message` objects, move them around, etc. This makes a very convenient interface for slicing-and-dicing MIME messages.

You can create a new object structure by creating `Message` instances, adding attachments and all the appropriate headers manually. For MIME messages though, the `email` package provides some convenient subclasses to make things easier.

Here are the classes:

```
class email.mime.base.MIMEBase(_maintype, _subtype, **_params)
Module: email.mime.base
```

This is the base class for all the MIME-specific subclasses of `Message`. Ordinarily you won't create instances specifically of `MIMEBase`, although you could. `MIMEBase` is provided primarily as a convenient base class for more specific MIME-aware subclasses.

`_maintype` is the *Content-Type* major type (e.g. `text` or `image`), and `_subtype` is the *Content-Type* minor type (e.g. `plain` or `gif`). `_params` is a parameter key/value dictionary and is passed directly to `Message.add_header()`.

The `MIMEBase` class always adds a *Content-Type* header (based on `_maintype`, `_subtype`, and `_params`), and a *MIME-Version* header (always set to 1.0).

```
class email.mime.nonmultipart.MIMENonMultipart
Module: email.mime.nonmultipart
```

A subclass of `MIMEBase`, this is an intermediate base class for MIME messages that are not *multipart*. The primary purpose of this class is to prevent the use of the `attach()` method, which only makes sense for *multipart* messages. If `attach()` is called, a `MultipartConversionError` exception is raised. New in version 2.2.2.

```
class email.mime.multipart.MIMEMultipart([_subtype[, boundary[, _subparts[, _params]]]])
Module: email.mime.multipart
```

A subclass of `MIMEBase`, this is an intermediate base class for MIME messages that are *multipart*. Optional `_subtype` defaults to `mixed`, but can be used to specify the subtype of the message. A *Content-Type* header of `multipart/_subtype` will be added to the message object. A *MIME-Version* header will also be added.

Optional `boundary` is the multipart boundary string. When `None` (the default), the boundary is calculated when needed (for example, when the message is serialized).

`_subparts` is a sequence of initial subparts for the payload. It must be possible to convert this sequence to a list. You can always attach new subparts to the message by using the `Message.attach()` method.

Additional parameters for the *Content-Type* header are taken from the keyword arguments, or passed into the `_params` argument, which is a keyword dictionary. New in version 2.2.2.

```
class email.mime.application.MIMEApplication(_data[, _subtype[, _encoder[, **_params]])
Module: email.mime.application
```

A subclass of `MIMENonMultipart`, the `MIMEApplication` class is used to represent MIME message objects of major type `application`. `_data` is a string containing the raw byte data. Optional `_subtype` specifies the MIME subtype and defaults to `octet-stream`.

Optional `_encoder` is a callable (i.e. function) which will perform the actual encoding of the data for transport. This callable takes one argument, which is the `MIMEApplication` instance. It should use `get_payload()` and `set_payload()` to change the payload to encoded form. It should also add any `Content-Transfer-Encoding` or other headers to the message object as necessary. The default encoding is base64. See the `email.encoders` module for a list of the built-in encoders.

`_params` are passed straight through to the base class constructor. New in version 2.5.

```
class email.mime.audio.MIMEAudio(_audiodata[, _subtype[, _encoder[, **_params ]]])
Module: email.mime.audio
```

A subclass of `MIMENonMultipart`, the `MIMEAudio` class is used to create MIME message objects of major type `audio`. `_audiodata` is a string containing the raw audio data. If this data can be decoded by the standard Python module `sndhdr`, then the subtype will be automatically included in the `Content-Type` header. Otherwise you can explicitly specify the audio subtype via the `_subtype` parameter. If the minor type could not be guessed and `_subtype` was not given, then `TypeError` is raised.

Optional `_encoder` is a callable (i.e. function) which will perform the actual encoding of the audio data for transport. This callable takes one argument, which is the `MIMEAudio` instance. It should use `get_payload()` and `set_payload()` to change the payload to encoded form. It should also add any `Content-Transfer-Encoding` or other headers to the message object as necessary. The default encoding is base64. See the `email.encoders` module for a list of the built-in encoders.

`_params` are passed straight through to the base class constructor.

```
class email.mime.image.MIMEImage(_imagedata[, _subtype[, _encoder[, **_params ]]])
Module: email.mime.image
```

A subclass of `MIMENonMultipart`, the `MIMEImage` class is used to create MIME message objects of major type `image`. `_imagedata` is a string containing the raw image data. If this data can be decoded by the standard Python module `imghdr`, then the subtype will be automatically included in the `Content-Type` header. Otherwise you can explicitly specify the image subtype via the `_subtype` parameter. If the minor type could not be guessed and `_subtype` was not given, then `TypeError` is raised.

Optional `_encoder` is a callable (i.e. function) which will perform the actual encoding of the image data for transport. This callable takes one argument, which is the `MIMEImage` instance. It should use `get_payload()` and `set_payload()` to change the payload to encoded form. It should also add any `Content-Transfer-Encoding` or other headers to the message object as necessary. The default encoding is base64. See the `email.encoders` module for a list of the built-in encoders.

`_params` are passed straight through to the `MIMEBase` constructor.

```
class email.mime.message.MIMEMessage(_msg[, _subtype ])
Module: email.mime.message
```

A subclass of `MIMENonMultipart`, the `MIMEMessage` class is used to create MIME objects of main type `message`. `_msg` is used as the payload, and must be an instance of class `Message` (or a subclass thereof), otherwise a `TypeError` is raised.

Optional `_subtype` sets the subtype of the message; it defaults to `rfc822`.

```
class email.mime.text.MIMEText(_text[, _subtype[, _charset ]])
Module: email.mime.text
```

A subclass of `MIMENonMultipart`, the `MIMEText` class is used to create MIME objects of major type `text`. `_text` is the string for the payload. `_subtype` is the minor type and defaults to `plain`. `_charset` is the character set of the text and is passed as a parameter to the `MIMENonMultipart` constructor; it defaults to

`us-ascii`. If `_text` is unicode, it is encoded using the `output_charset` of `_charset`, otherwise it is used as-is. Changed in version 2.4: The previously deprecated `_encoding` argument has been removed. Content Transfer Encoding now happens implicitly based on the `_charset` argument.

## 18.1.5 `email.header`: Internationalized headers

**RFC 2822** is the base standard that describes the format of email messages. It derives from the older **RFC 822** standard which came into widespread use at a time when most email was composed of ASCII characters only. **RFC 2822** is a specification written assuming email contains only 7-bit ASCII characters.

Of course, as email has been deployed worldwide, it has become internationalized, such that language specific character sets can now be used in email messages. The base standard still requires email messages to be transferred using only 7-bit ASCII characters, so a slew of RFCs have been written describing how to encode email containing non-ASCII characters into

**RFC 2822**-compliant format. These RFCs include **RFC 2045**, **RFC 2046**,

**RFC 2047**, and **RFC 2231**. The `email` package supports these standards in its `email.header` and `email.charset` modules.

If you want to include non-ASCII characters in your email headers, say in the `Subject` or `To` fields, you should use the `Header` class and assign the field in the `Message` object to an instance of `Header` instead of using a string for the header value. Import the `Header` class from the `email.header` module. For example:

```
>>> from email.message import Message
>>> from email.header import Header
>>> msg = Message()
>>> h = Header('p\u2013stal', 'iso-8859-1')
>>> msg['Subject'] = h
>>> print msg.as_string()
Subject: =?iso-8859-1?q?p=F6stal?='
```

Notice here how we wanted the `Subject` field to contain a non-ASCII character? We did this by creating a `Header` instance and passing in the character set that the byte string was encoded in. When the subsequent `Message` instance was flattened, the `Subject` field was properly **RFC 2047** encoded. MIME-aware mail readers would show this header using the embedded ISO-8859-1 character. New in version 2.2.2. Here is the `Header` class description:

```
class email.header.Header ([s[, charset[, maxlinelen[, header_name[, continuation_ws[, errors ]]]]])
```

Create a MIME-compliant header that can contain strings in different character sets.

Optional `s` is the initial header value. If `None` (the default), the initial header value is not set. You can later append to the header with `append()` method calls. `s` may be a byte string or a Unicode string, but see the `append()` documentation for semantics.

Optional `charset` serves two purposes: it has the same meaning as the `charset` argument to the `append()` method. It also sets the default character set for all subsequent `append()` calls that omit the `charset` argument. If `charset` is not provided in the constructor (the default), the `us-ascii` character set is used both as `s`'s initial charset and as the default for subsequent `append()` calls.

The maximum line length can be specified explicitly via `maxlinelen`. For splitting the first line to a shorter value (to account for the field header which isn't included in `s`, e.g. `Subject`) pass in the name of the field in `header_name`. The default `maxlinelen` is 76, and the default value for `header_name` is `None`, meaning it is not taken into account for the first line of a long, split header.

Optional `continuation_ws` must be **RFC 2822**-compliant folding whitespace, and is usually either a space or a hard tab character. This character will be prepended to continuation lines. `continuation_ws` defaults to a single space character (" ").

Optional *errors* is passed straight through to the `append()` method.

**append** (*s* [, *charset* [, *errors* ] ])

Append the string *s* to the MIME header.

Optional *charset*, if given, should be a `Charset` instance (see `email.charset`) or the name of a character set, which will be converted to a `Charset` instance. A value of `None` (the default) means that the *charset* given in the constructor is used.

*s* may be a byte string or a Unicode string. If it is a byte string (i.e. `isinstance(s, str)` is true), then *charset* is the encoding of that byte string, and a `UnicodeError` will be raised if the string cannot be decoded with that character set.

If *s* is a Unicode string, then *charset* is a hint specifying the character set of the characters in the string. In this case, when producing an **RFC 2822**-compliant header using **RFC 2047** rules, the Unicode string will be encoded using the following charsets in order: `us-ascii`, the *charset* hint, `utf-8`. The first character set to not provoke a `UnicodeError` is used.

Optional *errors* is passed through to any `unicode()` or `ustr.encode()` call, and defaults to “strict”.

**encode** ([*splitchars* ])

Encode a message header into an RFC-compliant format, possibly wrapping long lines and encapsulating non-ASCII parts in base64 or quoted-printable encodings. Optional *splitchars* is a string containing characters to split long ASCII lines on, in rough support of **RFC 2822**’s *highest level syntactic breaks*. This doesn’t affect **RFC 2047** encoded lines.

The `Header` class also provides a number of methods to support standard operators and built-in functions.

**\_\_str\_\_** ()

A synonym for `Header.encode()`. Useful for `str(aHeader)`.

**\_\_unicode\_\_** ()

A helper for the built-in `unicode()` function. Returns the header as a Unicode string.

**\_\_eq\_\_** (*other*)

This method allows you to compare two `Header` instances for equality.

**\_\_ne\_\_** (*other*)

This method allows you to compare two `Header` instances for inequality.

The `email.header` module also provides the following convenient functions.

`email.header.decode_header` (*header*)

Decode a message header value without converting the character set. The header value is in *header*.

This function returns a list of (`decoded_string`, `charset`) pairs containing each of the decoded parts of the header. *charset* is `None` for non-encoded parts of the header, otherwise a lower case string containing the name of the character set specified in the encoded string.

Here’s an example:

```
>>> from email.header import decode_header
>>> decode_header('=?iso-8859-1?q?p=F6stal?=' )
[('p\xxf6stal', 'iso-8859-1')]
```

`email.header.make_header` (*decoded\_seq* [, *maxlinelen* [, *header\_name* [, *continuation\_ws* ] ] ])

Create a `Header` instance from a sequence of pairs as returned by `decode_header()`.

`decode_header()` takes a header value string and returns a sequence of pairs of the format (`decoded_string`, `charset`) where *charset* is the name of the character set.

This function takes one of those sequence of pairs and returns a `Header` instance. Optional *maxlinelen*, *header\_name*, and *continuation\_ws* are as in the `Header` constructor.

### 18.1.6 `email.charset`: Representing character sets

This module provides a class `Charset` for representing character sets and character set conversions in email messages, as well as a character set registry and several convenience methods for manipulating this registry. Instances of `Charset` are used in several other modules within the `email` package.

Import this class from the `email.charset` module. New in version 2.2.2.

**class** `email.charset.Charset` (`[input_charset]`)

Map character sets to their email properties.

This class provides information about the requirements imposed on email for a specific character set. It also provides convenience routines for converting between character sets, given the availability of the applicable codecs. Given a character set, it will do its best to provide information on how to use that character set in an email message in an RFC-compliant way.

Certain character sets must be encoded with quoted-printable or base64 when used in email headers or bodies. Certain character sets must be converted outright, and are not allowed in email.

Optional *input\_charset* is as described below; it is always coerced to lower case. After being alias normalized it is also used as a lookup into the registry of character sets to find out the header encoding, body encoding, and output conversion codec to be used for the character set. For example, if *input\_charset* is `iso-8859-1`, then headers and bodies will be encoded using quoted-printable and no output conversion codec is necessary. If *input\_charset* is `eu- jp`, then headers will be encoded with base64, bodies will not be encoded, but output text will be converted from the `eu- jp` character set to the `iso-2022- jp` character set.

`Charset` instances have the following data attributes:

**`input_charset`**

The initial character set specified. Common aliases are converted to their *official* email names (e.g. `latin_1` is converted to `iso-8859-1`). Defaults to 7-bit `us-ascii`.

**`header_encoding`**

If the character set must be encoded before it can be used in an email header, this attribute will be set to `Charset.QP` (for quoted-printable), `Charset.BASE64` (for base64 encoding), or `Charset.SHORTEST` for the shortest of QP or BASE64 encoding. Otherwise, it will be `None`.

**`body_encoding`**

Same as *header\_encoding*, but describes the encoding for the mail message's body, which indeed may be different than the header encoding. `Charset.SHORTEST` is not allowed for *body\_encoding*.

**`output_charset`**

Some character sets must be converted before they can be used in email headers or bodies. If the *input\_charset* is one of them, this attribute will contain the name of the character set output will be converted to. Otherwise, it will be `None`.

**`input_codec`**

The name of the Python codec used to convert the *input\_charset* to Unicode. If no conversion codec is necessary, this attribute will be `None`.

**`output_codec`**

The name of the Python codec used to convert Unicode to the *output\_charset*. If no conversion codec is necessary, this attribute will have the same value as the *input\_codec*.

`Charset` instances also have the following methods:

**get\_body\_encoding()**

Return the content transfer encoding used for body encoding.

This is either the string `quoted-printable` or `base64` depending on the encoding used, or it is a function, in which case you should call the function with a single argument, the `Message` object being encoded. The function should then set the `Content-Transfer-Encoding` header itself to whatever is appropriate.

Returns the string `quoted-printable` if `body_encoding` is `QP`, returns the string `base64` if `body_encoding` is `BASE64`, and returns the string `7bit` otherwise.

**convert(s)**

Convert the string `s` from the `input_codec` to the `output_codec`.

**toSplittable(s)**

Convert a possibly multibyte string to a safely splittable format. `s` is the string to split.

Uses the `input_codec` to try and convert the string to Unicode, so it can be safely split on character boundaries (even for multibyte characters).

Returns the string as-is if it isn't known how to convert `s` to Unicode with the `input_charset`.

Characters that could not be converted to Unicode will be replaced with the Unicode replacement character `'U+FFFD'`.

**fromSplittable(ustr[, to\_output])**

Convert a splittable string back into an encoded string. `ustr` is a Unicode string to “unsplit”.

This method uses the proper codec to try and convert the string from Unicode back into an encoded format. Return the string as-is if it is not Unicode, or if it could not be converted from Unicode.

Characters that could not be converted from Unicode will be replaced with an appropriate character (usually `'?'`).

If `to_output` is `True` (the default), uses `output_codec` to convert to an encoded format. If `to_output` is `False`, it uses `input_codec`.

**get\_output\_charset()**

Return the output character set.

This is the `output_charset` attribute if that is not `None`, otherwise it is `input_charset`.

**encoded\_header\_len()**

Return the length of the encoded header string, properly calculating for quoted-printable or base64 encoding.

**header\_encode(s[, convert])**

Header-encode the string `s`.

If `convert` is `True`, the string will be converted from the input charset to the output charset automatically. This is not useful for multibyte character sets, which have line length issues (multibyte characters must be split on a character, not a byte boundary); use the higher-level `Header` class to deal with these issues (see `email.header`). `convert` defaults to `False`.

The type of encoding (base64 or quoted-printable) will be based on the `header_encoding` attribute.

**body\_encode(s[, convert])**

Body-encode the string `s`.

If `convert` is `True` (the default), the string will be converted from the input charset to output charset automatically. Unlike `header_encode()`, there are no issues with byte boundaries and multibyte charsets in email bodies, so this is usually pretty safe.

The type of encoding (base64 or quoted-printable) will be based on the `body_encoding` attribute.

The `Charset` class also provides a number of methods to support standard operations and built-in functions.

`__str__()`

Returns `input_charset` as a string coerced to lower case. `__repr__()` is an alias for `__str__()`.

`__eq__(other)`

This method allows you to compare two `Charset` instances for equality.

`__ne__(other)`

This method allows you to compare two `Charset` instances for inequality.

The `email.charset` module also provides the following functions for adding new entries to the global character set, alias, and codec registries:

`email.charset.add_charset(charset[, header_enc[, body_enc[, output_charset ] ]])`

Add character properties to the global registry.

`charset` is the input character set, and must be the canonical name of a character set.

Optional `header_enc` and `body_enc` is either `Charset.QP` for quoted-printable, `Charset.BASE64` for base64 encoding, `Charset.SHORTEST` for the shortest of quoted-printable or base64 encoding, or `None` for no encoding. `SHORTEST` is only valid for `header_enc`. The default is `None` for no encoding.

Optional `output_charset` is the character set that the output should be in. Conversions will proceed from input charset, to Unicode, to the output charset when the method `Charset.convert()` is called. The default is to output in the same character set as the input.

Both `input_charset` and `output_charset` must have Unicode codec entries in the module's character set-to-codec mapping; use `add_codec()` to add codecs the module does not know about. See the `codecs` module's documentation for more information.

The global character set registry is kept in the module global dictionary `CHARSETS`.

`email.charset.add_alias(alias, canonical)`

Add a character set alias. `alias` is the alias name, e.g. `latin-1`. `canonical` is the character set's canonical name, e.g. `iso-8859-1`.

The global charset alias registry is kept in the module global dictionary `ALIASES`.

`email.charset.add_codec(charset, codecname)`

Add a codec that map characters in the given character set to and from Unicode.

`charset` is the canonical name of a character set. `codecname` is the name of a Python codec, as appropriate for the second argument to the `unicode()` built-in, or to the `encode()` method of a Unicode string.

## 18.1.7 email.encoders: Encoders

When creating `Message` objects from scratch, you often need to encode the payloads for transport through compliant mail servers. This is especially true for `image/*` and `text/*` type messages containing binary data.

The `email` package provides some convenient encodings in its `encoders` module. These encoders are actually used by the `MIMEAudio` and `MIMEImage` class constructors to provide default encodings. All encoder functions take exactly one argument, the message object to encode. They usually extract the payload, encode it, and reset the payload to this newly encoded value. They should also set the `Content-Transfer-Encoding` header as appropriate.

Note that these functions are not meaningful for a multipart message. They must be applied to individual subparts instead, and will raise a `TypeError` if passed a message whose type is multipart.

Here are the encoding functions provided:

`email.encoders.encode_quopri` (*msg*)

Encodes the payload into quoted-printable form and sets the *Content-Transfer-Encoding* header to `quoted-printable`<sup>3</sup>. This is a good encoding to use when most of your payload is normal printable data, but contains a few unprintable characters.

`email.encoders.encode_base64` (*msg*)

Encodes the payload into base64 form and sets the *Content-Transfer-Encoding* header to `base64`. This is a good encoding to use when most of your payload is unprintable data since it is a more compact form than quoted-printable. The drawback of base64 encoding is that it renders the text non-human readable.

`email.encoders.encode_7or8bit` (*msg*)

This doesn't actually modify the message's payload, but it does set the *Content-Transfer-Encoding* header to either `7bit` or `8bit` as appropriate, based on the payload data.

`email.encoders.encode_noop` (*msg*)

This does nothing; it doesn't even set the *Content-Transfer-Encoding* header.

### 18.1.8 email.errors: Exception and Defect classes

The following exception classes are defined in the `email.errors` module:

**exception** `email.errors.MessageError`

This is the base class for all exceptions that the `email` package can raise. It is derived from the standard `Exception` class and defines no additional methods.

**exception** `email.errors.MessageParseError`

This is the base class for exceptions raised by the `Parser` class. It is derived from `MessageError`.

**exception** `email.errors.HeaderParseError`

Raised under some error conditions when parsing the **RFC 2822** headers of a message, this class is derived from `MessageParseError`. It can be raised from the `Parser.parse()` or `Parser.parsestr()` methods.

Situations where it can be raised include finding an envelope header after the first **RFC 2822** header of the message, finding a continuation line before the first **RFC 2822** header is found, or finding a line in the headers which is neither a header or a continuation line.

**exception** `email.errors.BoundaryError`

Raised under some error conditions when parsing the **RFC 2822** headers of a message, this class is derived from `MessageParseError`. It can be raised from the `Parser.parse()` or `Parser.parsestr()` methods.

Situations where it can be raised include not being able to find the starting or terminating boundary in a *multipart/\** message when strict parsing is used.

**exception** `email.errors.MultipartConversionError`

Raised when a payload is added to a `Message` object using `add_payload()`, but the payload is already a scalar and the message's *Content-Type* main type is not either *multipart* or missing. `MultipartConversionError` multiply inherits from `MessageError` and the built-in `TypeError`.

Since `Message.add_payload()` is deprecated, this exception is rarely raised in practice. However the exception may also be raised if the `attach()` method is called on an instance of a class derived from `MIMENonMultipart` (e.g. `MIMEImage`).

Here's the list of the defects that the `FeedParser` can find while parsing messages. Note that the defects are added to the message where the problem was found, so for example, if a message nested inside a *multipart/alternative* had a malformed header, that nested message object would have a defect, but the containing messages would not.

All defect classes are subclassed from `email.errors.MessageDefect`, but this class is *not* an exception! New in version 2.4: All the defect classes were added.

<sup>3</sup> Note that encoding with `encode_quopri()` also encodes all tabs and space characters in the data.

- `NoBoundaryInMultipartDefect` – A message claimed to be a multipart, but had no *boundary* parameter.
- `StartBoundaryNotFoundDefect` – The start boundary claimed in the *Content-Type* header was never found.
- `FirstHeaderLineIsContinuationDefect` – The message had a continuation line as its first header line.
- `MisplacedEnvelopeHeaderDefect` – A “Unix From” header was found in the middle of a header block.
- `MalformedHeaderDefect` – A header was found that was missing a colon, or was otherwise malformed.
- `MultipartInvariantViolationDefect` – A message claimed to be a *multipart*, but no subparts were found. Note that when a message has this defect, its `is_multipart()` method may return false even though its content type claims to be *multipart*.

### 18.1.9 `email.utils`: Miscellaneous utilities

There are several useful utilities provided in the `email.utils` module:

`email.utils.quote(str)`

Return a new string with backslashes in *str* replaced by two backslashes, and double quotes replaced by backslash-double quote.

`email.utils.unquote(str)`

Return a new string which is an *unquoted* version of *str*. If *str* ends and begins with double quotes, they are stripped off. Likewise if *str* ends and begins with angle brackets, they are stripped off.

`email.utils.parseaddr(address)`

Parse address – which should be the value of some address-containing field such as *To* or *Cc* – into its constituent *realname* and *email address* parts. Returns a tuple of that information, unless the parse fails, in which case a 2-tuple of (“”, “”) is returned.

`email.utils.formataddr(pair)`

The inverse of `parseaddr()`, this takes a 2-tuple of the form (*realname*, *email\_address*) and returns the string value suitable for a *To* or *Cc* header. If the first element of *pair* is false, then the second element is returned unmodified.

`email.utils.getaddresses(fieldvalues)`

This method returns a list of 2-tuples of the form returned by `parseaddr()`. *fieldvalues* is a sequence of header field values as might be returned by `Message.get_all()`. Here’s a simple example that gets all the recipients of a message:

```
from email.utils import getaddresses

tos = msg.get_all('to', [])
ccs = msg.get_all('cc', [])
resent_tos = msg.get_all('resent-to', [])
resent_ccs = msg.get_all('resent-cc', [])
all_recipients = getaddresses(tos + ccs + resent_tos + resent_ccs)
```

`email.utils.parsedate(date)`

Attempts to parse a date according to the rules in **RFC 2822**. However, some mailers don’t follow that format as specified, so `parsedate()` tries to guess correctly in such cases. *date* is a string containing an **RFC 2822** date, such as “Mon, 20 Nov 1995 19:12:08 -0500”. If it succeeds in parsing the date, `parsedate()` returns a 9-tuple that can be passed directly to `time.mktime()`; otherwise `None` will be returned. Note that indexes 6, 7, and 8 of the result tuple are not usable.

`email.utils.parsedate_tz` (*date*)

Performs the same function as `parsedate()`, but returns either `None` or a 10-tuple; the first 9 elements make up a tuple that can be passed directly to `time.mktime()`, and the tenth is the offset of the date's timezone from UTC (which is the official term for Greenwich Mean Time)<sup>4</sup>. If the input string has no timezone, the last element of the tuple returned is `None`. Note that indexes 6, 7, and 8 of the result tuple are not usable.

`email.utils.mktime_tz` (*tuple*)

Turn a 10-tuple as returned by `parsedate_tz()` into a UTC timestamp. If the timezone item in the tuple is `None`, assume local time. Minor deficiency: `mktime_tz()` interprets the first 8 elements of *tuple* as a local time and then compensates for the timezone difference. This may yield a slight error around changes in daylight savings time, though not worth worrying about for common use.

`email.utils.formatdate` (*[timeval[, localtime][, usegmt]]*)

Returns a date string as per [RFC 2822](#), e.g.:

```
Fri, 09 Nov 2001 01:08:47 -0000
```

Optional *timeval* if given is a floating point time value as accepted by `time.gmtime()` and `time.localtime()`, otherwise the current time is used.

Optional *localtime* is a flag that when `True`, interprets *timeval*, and returns a date relative to the local timezone instead of UTC, properly taking daylight savings time into account. The default is `False` meaning UTC is used.

Optional *usegmt* is a flag that when `True`, outputs a date string with the timezone as an ascii string GMT, rather than a numeric `-0000`. This is needed for some protocols (such as HTTP). This only applies when *localtime* is `False`. The default is `False`. New in version 2.4.

`email.utils.make_msgid` (*[idstring]*)

Returns a string suitable for an [RFC 2822](#)-compliant *Message-ID* header. Optional *idstring* if given, is a string used to strengthen the uniqueness of the message id.

`email.utils.decode_rfc2231` (*s*)

Decode the string *s* according to [RFC 2231](#).

`email.utils.encode_rfc2231` (*s*, *charset*, *language*)

Encode the string *s* according to [RFC 2231](#). Optional *charset* and *language*, if given is the character set name and language name to use. If neither is given, *s* is returned as-is. If *charset* is given but *language* is not, the string is encoded using the empty string for *language*.

`email.utils.collapse_rfc2231_value` (*value*, *errors*, *fallback\_charset*)

When a header parameter is encoded in [RFC 2231](#) format, `Message.get_param()` may return a 3-tuple containing the character set, language, and value. `collapse_rfc2231_value()` turns this into a unicode string. Optional *errors* is passed to the *errors* argument of the built-in `unicode()` function; it defaults to `replace`. Optional *fallback\_charset* specifies the character set to use if the one in the

[RFC 2231](#) header is not known by Python; it defaults to `us-ascii`.

For convenience, if the *value* passed to `collapse_rfc2231_value()` is not a tuple, it should be a string and it is returned unquoted.

`email.utils.decode_params` (*params*)

Decode parameters list according to [RFC 2231](#). *params* is a sequence of 2-tuples containing elements of the form (content-type, string-value).

Changed in version 2.4: The `dump_address_pair()` function has been removed; use `formataddr()` instead. Changed in version 2.4: The `decode()` function has been removed; use the `Header.decode_header()`

<sup>4</sup> Note that the sign of the timezone offset is the opposite of the sign of the `time.timezone` variable for the same timezone; the latter variable follows the POSIX standard while this module follows [RFC 2822](#).

method instead. Changed in version 2.4: The `encode()` function has been removed; use the `Header.encode()` method instead.

### 18.1.10 `email.iterators`: Iterators

Iterating over a message object tree is fairly easy with the `Message.walk()` method. The `email.iterators` module provides some useful higher level iterations over message object trees.

`email.iterators.body_line_iterator(msg[, decode])`

This iterates over all the payloads in all the subparts of `msg`, returning the string payloads line-by-line. It skips over all the subpart headers, and it skips over any subpart with a payload that isn't a Python string. This is somewhat equivalent to reading the flat text representation of the message from a file using `readline()`, skipping over all the intervening headers.

Optional `decode` is passed through to `Message.get_payload()`.

`email.iterators.typed_subpart_iterator(msg[, maintype[, subtype]])`

This iterates over all the subparts of `msg`, returning only those subparts that match the MIME type specified by `maintype` and `subtype`.

Note that `subtype` is optional; if omitted, then subpart MIME type matching is done only with the main type. `maintype` is optional too; it defaults to `text`.

Thus, by default `typed_subpart_iterator()` returns each subpart that has a MIME type of `text/*`.

The following function has been added as a useful debugging tool. It should *not* be considered part of the supported public interface for the package.

`email.iterators._structure(msg[, fp[, level]])`

Prints an indented representation of the content types of the message object structure. For example:

```
>>> msg = email.message_from_file(somefile)
>>> _structure(msg)
multipart/mixed
  text/plain
  text/plain
  multipart/digest
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
  text/plain
```

Optional `fp` is a file-like object to print the output to. It must be suitable for Python's extended print statement. `level` is used internally.

### 18.1.11 `email`: Examples

Here are a few examples of how to use the `email` package to read, write, and send simple email messages, as well as more complex MIME messages.

First, let's see how to create and send a simple text message:

```
# Import smtplib for the actual sending function
import smtplib

# Import the email modules we'll need
from email.mime.text import MIMEText

# Open a plain text file for reading. For this example, assume that
# the text file contains only ASCII characters.
fp = open(textfile, 'rb')
# Create a text/plain message
msg = MIMEText(fp.read())
fp.close()

# me == the sender's email address
# you == the recipient's email address
msg['Subject'] = 'The contents of %s' % textfile
msg['From'] = me
msg['To'] = you

# Send the message via our own SMTP server, but don't include the
# envelope header.
s = smtplib.SMTP('localhost')
s.sendmail(me, [you], msg.as_string())
s.quit()
```

And parsing RFC822 headers can easily be done by the `parse(filename)` or `parsestr(message_as_string)` methods of the `Parser()` class:

```
# Import the email modules we'll need
from email.parser import Parser

# If the e-mail headers are in a file, uncomment this line:
#headers = Parser().parse(open(messagefile, 'r'))

# Or for parsing headers in a string, use:
headers = Parser().parsestr('From: <user@example.com>\n'
    'To: <someone_else@example.com>\n'
    'Subject: Test message\n'
    '\n'
    'Body would go here\n')

# Now the header items can be accessed as a dictionary:
print 'To: %s' % headers['to']
print 'From: %s' % headers['from']
print 'Subject: %s' % headers['subject']
```

Here's an example of how to send a MIME message containing a bunch of family pictures that may be residing in a directory:

```
# Import smtplib for the actual sending function
import smtplib

# Here are the email package modules we'll need
from email.mime.image import MIMEImage
```

```
from email.mime.multipart import MIMEMultipart

COMMASPACE = ', '

# Create the container (outer) email message.
msg = MIMEMultipart()
msg['Subject'] = 'Our family reunion'
# me == the sender's email address
# family = the list of all recipients' email addresses
msg['From'] = me
msg['To'] = COMMASPACE.join(family)
msg.preamble = 'Our family reunion'

# Assume we know that the image files are all in PNG format
for file in pngfiles:
    # Open the files in binary mode. Let the MIMEImage class automatically
    # guess the specific image type.
    fp = open(file, 'rb')
    img = MIMEImage(fp.read())
    fp.close()
    msg.attach(img)

# Send the email via our own SMTP server.
s = smtplib.SMTP('localhost')
s.sendmail(me, family, msg.as_string())
s.quit()
```

Here's an example of how to send the entire contents of a directory as an email message: <sup>5</sup>

```
#!/usr/bin/env python

"""Send the contents of a directory as a MIME message."""

import os
import sys
import smtplib
# For guessing MIME type based on file name extension
import mimetypes

from optparse import OptionParser

from email import encoders
from email.message import Message
from email.mime.audio import MIMEAudio
from email.mime.base import MIMEBase
from email.mime.image import MIMEImage
from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText

COMMASPACE = ', '

def main():
```

---

<sup>5</sup> Thanks to Matthew Dixon Cowles for the original inspiration and examples.

```

    parser = OptionParser(usage="""\
Send the contents of a directory as a MIME message.

```

```

Usage: %prog [options]

```

Unless the `-o` option is given, the email is sent by forwarding to your local SMTP server, which then does the normal delivery process. Your local machine must be running an SMTP server.

```

""")
    parser.add_option('-d', '--directory',
                      type='string', action='store',
                      help="""Mail the contents of the specified directory,
otherwise use the current directory. Only the regular
files in the directory are sent, and we don't recurse to
subdirectories.""")
    parser.add_option('-o', '--output',
                      type='string', action='store', metavar='FILE',
                      help="""Print the composed message to FILE instead of
sending the message to the SMTP server.""")
    parser.add_option('-s', '--sender',
                      type='string', action='store', metavar='SENDER',
                      help='The value of the From: header (required)')
    parser.add_option('-r', '--recipient',
                      type='string', action='append', metavar='RECIPIENT',
                      default=[], dest='recipients',
                      help='A To: header value (at least one required)')

    opts, args = parser.parse_args()
    if not opts.sender or not opts.recipients:
        parser.print_help()
        sys.exit(1)

    directory = opts.directory
    if not directory:
        directory = '.'

    # Create the enclosing (outer) message
    outer = MIMEMultipart()
    outer['Subject'] = 'Contents of directory %s' % os.path.abspath(directory)
    outer['To'] = COMMASPACE.join(opts.recipients)
    outer['From'] = opts.sender
    outer.preamble = 'You will not see this in a MIME-aware mail reader.\n'

    for filename in os.listdir(directory):
        path = os.path.join(directory, filename)
        if not os.path.isfile(path):
            continue

        # Guess the content type based on the file's extension. Encoding
        # will be ignored, although we should check for simple things like
        # gzip'd or compressed files.
        ctype, encoding = mimetypes.guess_type(path)
        if ctype is None or encoding is not None:
            # No guess could be made, or the file is encoded (compressed), so
            # use a generic bag-of-bits type.
            ctype = 'application/octet-stream'
        maintype, subtype = ctype.split('/', 1)
        if maintype == 'text':

```

```
    fp = open(path)
    # Note: we should handle calculating the charset
    msg = MIMEText(fp.read(), _subtype=subtype)
    fp.close()
    elif maintype == 'image':
        fp = open(path, 'rb')
        msg = MIMEImage(fp.read(), _subtype=subtype)
        fp.close()
    elif maintype == 'audio':
        fp = open(path, 'rb')
        msg = MIMEAudio(fp.read(), _subtype=subtype)
        fp.close()
    else:
        fp = open(path, 'rb')
        msg = MIMEBase(maintype, subtype)
        msg.set_payload(fp.read())
        fp.close()
        # Encode the payload using Base64
        encoders.encode_base64(msg)
        # Set the filename parameter
        msg.add_header('Content-Disposition', 'attachment', filename=filename)
    outer.attach(msg)

# Now send or store the message
composed = outer.as_string()
if opts.output:
    fp = open(opts.output, 'w')
    fp.write(composed)
    fp.close()
else:
    s = smtplib.SMTP('localhost')
    s.sendmail(opts.sender, opts.recipients, composed)
    s.quit()

if __name__ == '__main__':
    main()
```

Here's an example of how to unpack a MIME message like the one above, into a directory of files:

```
#!/usr/bin/env python

"""Unpack a MIME message into a directory of files."""

import os
import sys
import email
import errno
import mimetypes

from optparse import OptionParser

def main():
    parser = OptionParser(usage="""\
Unpack a MIME message into a directory of files.
```

```

Usage: %prog [options] msgfile
"""
    parser.add_option('-d', '--directory',
                      type='string', action='store',
                      help="""Unpack the MIME message into the named
                      directory, which will be created if it doesn't already
                      exist.""")

    opts, args = parser.parse_args()
    if not opts.directory:
        parser.print_help()
        sys.exit(1)

    try:
        msgfile = args[0]
    except IndexError:
        parser.print_help()
        sys.exit(1)

    try:
        os.mkdir(opts.directory)
    except OSError, e:
        # Ignore directory exists error
        if e.errno != errno.EEXIST:
            raise

    fp = open(msgfile)
    msg = email.message_from_file(fp)
    fp.close()

    counter = 1
    for part in msg.walk():
        # multipart/* are just containers
        if part.get_content_maintype() == 'multipart':
            continue
        # Applications should really sanitize the given filename so that an
        # email message can't be used to overwrite important files
        filename = part.get_filename()
        if not filename:
            ext = mimetypes.guess_extension(part.get_content_type())
            if not ext:
                # Use a generic bag-of-bits extension
                ext = '.bin'
            filename = 'part-%03d%s' % (counter, ext)
        counter += 1
        fp = open(os.path.join(opts.directory, filename), 'wb')
        fp.write(part.get_payload(decode=True))
        fp.close()

if __name__ == '__main__':
    main()

```

Here's an example of how to create an HTML message with an alternative plain text version: <sup>6</sup>

```
#!/usr/bin/env python

import smtplib

from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText

# me == my email address
# you == recipient's email address
me = "my@email.com"
you = "your@email.com"

# Create message container - the correct MIME type is multipart/alternative.
msg = MIMEMultipart('alternative')
msg['Subject'] = "Link"
msg['From'] = me
msg['To'] = you

# Create the body of the message (a plain-text and an HTML version).
text = "Hi!\nHow are you?\nHere is the link you wanted:\nhttp://www.python.org"
html = """\
<html>
  <head></head>
  <body>
    <p>Hi!<br>
      How are you?<br>
      Here is the <a href="http://www.python.org">link</a> you wanted.
    </p>
  </body>
</html>
"""

# Record the MIME types of both parts - text/plain and text/html.
part1 = MIMEText(text, 'plain')
part2 = MIMEText(html, 'html')

# Attach parts into message container.
# According to RFC 2046, the last part of a multipart message, in this case
# the HTML message, is best and preferred.
msg.attach(part1)
msg.attach(part2)

# Send the message via local SMTP server.
s = smtplib.SMTP('localhost')
# sendmail function takes 3 arguments: sender's address, recipient's address
# and message to send - here it is sent as one string.
s.sendmail(me, you, msg.as_string())
s.quit()
```

### See Also:

Module `smtplib` SMTP protocol client

---

<sup>6</sup> Contributed by Martin Matejek.

Module `nntplib` NNTP protocol client

### 18.1.12 Package History

This table describes the release history of the email package, corresponding to the version of Python that the package was released with. For purposes of this document, when you see a note about change or added versions, these refer to the Python version the change was made in, *not* the email package version. This table also describes the Python compatibility of each version of the package.

email version	distributed with	compatible with
1.x	Python 2.2.0 to Python 2.2.1	<i>no longer supported</i>
2.5	Python 2.2.2+ and Python 2.3	Python 2.1 to 2.5
3.0	Python 2.4	Python 2.3 to 2.5
4.0	Python 2.5	Python 2.3 to 2.5

Here are the major differences between `email` version 4 and version 3:

- All modules have been renamed according to **PEP 8** standards. For example, the version 3 module `email.Message` was renamed to `email.message` in version 4.
- A new subpackage `email.mime` was added and all the version 3 `email.MIME*` modules were renamed and situated into the `email.mime` subpackage. For example, the version 3 module `email.MIMEText` was renamed to `email.mime.text`.

*Note that the version 3 names will continue to work until Python 2.6.*

- The `email.mime.application` module was added, which contains the `MIMEApplication` class.
- Methods that were deprecated in version 3 have been removed. These include `Generator.__call__()`, `Message.get_type()`, `Message.get_main_type()`, `Message.get_subtype()`.
- Fixes have been added for **RFC 2231** support which can change some of the return types for `Message.get_param()` and friends. Under some circumstances, values which used to return a 3-tuple now return simple strings (specifically, if all extended parameter segments were unencoded, there is no language and charset designation expected, so the return type is now a simple string). Also, %-decoding used to be done for both encoded and unencoded segments; this decoding is now done only for encoded segments.

Here are the major differences between `email` version 3 and version 2:

- The `FeedParser` class was introduced, and the `Parser` class was implemented in terms of the `FeedParser`. All parsing therefore is non-strict, and parsing will make a best effort never to raise an exception. Problems found while parsing messages are stored in the message's `defect` attribute.
- All aspects of the API which raised `DeprecationWarnings` in version 2 have been removed. These include the `_encoder` argument to the `MIMEText` constructor, the `Message.add_payload()` method, the `Utils.dump_address_pair()` function, and the functions `Utils.decode()` and `Utils.encode()`.
- New `DeprecationWarnings` have been added to: `Generator.__call__()`, `Message.get_type()`, `Message.get_main_type()`, `Message.get_subtype()`, and the `strict` argument to the `Parser` class. These are expected to be removed in future versions.
- Support for Pythons earlier than 2.3 has been removed.

Here are the differences between `email` version 2 and version 1:

- The `email.Header` and `email.Charset` modules have been added.
- The pickle format for `Message` instances has changed. Since this was never (and still isn't) formally defined, this isn't considered a backward incompatibility. However if your application pickles and unpickles `Message`

instances, be aware that in `email` version 2, `Message` instances now have private variables `_charset` and `_default_type`.

- Several methods in the `Message` class have been deprecated, or their signatures changed. Also, many new methods have been added. See the documentation for the `Message` class for details. The changes should be completely backward compatible.
- The object structure has changed in the face of `message/rfc822` content types. In `email` version 1, such a type would be represented by a scalar payload, i.e. the container message's `is_multipart()` returned false, `get_payload()` was not a list object, but a single `Message` instance.

This structure was inconsistent with the rest of the package, so the object representation for `message/rfc822` content types was changed. In `email` version 2, the container *does* return True from `is_multipart()`, and `get_payload()` returns a list containing a single `Message` item.

Note that this is one place that backward compatibility could not be completely maintained. However, if you're already testing the return type of `get_payload()`, you should be fine. You just need to make sure your code doesn't do a `set_payload()` with a `Message` instance on a container with a content type of `message/rfc822`.

- The `Parser` constructor's `strict` argument was added, and its `parse()` and `parsestr()` methods grew a `headersonly` argument. The `strict` flag was also added to functions `email.message_from_file()` and `email.message_from_string()`.
- `Generator.__call__()` is deprecated; use `Generator.flatten()` instead. The `Generator` class has also grown the `clone()` method.
- The `DecodedGenerator` class in the `email.Generator` module was added.
- The intermediate base classes `MIMENonMultipart` and `MIMEMultipart` have been added, and interposed in the class hierarchy for most of the other MIME-related derived classes.
- The `_encoder` argument to the `MIMEText` constructor has been deprecated. Encoding now happens implicitly based on the `_charset` argument.
- The following functions in the `email.Utils` module have been deprecated: `dump_address_pairs()`, `decode()`, and `encode()`. The following functions have been added to the module: `make_msgid()`, `decode_rfc2231()`, `encode_rfc2231()`, and `decode_params()`.
- The non-public function `email.Iterators._structure()` was added.

### 18.1.13 Differences from `mimelib`

The `email` package was originally prototyped as a separate library called `mimelib`. Changes have been made so that method names are more consistent, and some methods or modules have either been added or removed. The semantics of some of the methods have also changed. For the most part, any functionality available in `mimelib` is still available in the `email` package, albeit often in a different way. Backward compatibility between the `mimelib` package and the `email` package was not a priority.

Here is a brief description of the differences between the `mimelib` and the `email` packages, along with hints on how to port your applications.

Of course, the most visible difference between the two packages is that the package name has been changed to `email`. In addition, the top-level package has the following differences:

- `messageFromString()` has been renamed to `message_from_string()`.
- `messageFromFile()` has been renamed to `message_from_file()`.

The `Message` class has the following differences:

- The method `asString()` was renamed to `as_string()`.

- The method `ismultipart()` was renamed to `is_multipart()`.
- The `get_payload()` method has grown a *decode* optional argument.
- The method `getall()` was renamed to `get_all()`.
- The method `addheader()` was renamed to `add_header()`.
- The method `gettype()` was renamed to `get_type()`.
- The method `getmaintype()` was renamed to `get_main_type()`.
- The method `getsubtype()` was renamed to `get_subtype()`.
- The method `getparams()` was renamed to `get_params()`. Also, whereas `getparams()` returned a list of strings, `get_params()` returns a list of 2-tuples, effectively the key/value pairs of the parameters, split on the '=' sign.
- The method `getparam()` was renamed to `get_param()`.
- The method `getcharsets()` was renamed to `get_charsets()`.
- The method `getfilename()` was renamed to `get_filename()`.
- The method `getboundary()` was renamed to `get_boundary()`.
- The method `setboundary()` was renamed to `set_boundary()`.
- The method `getdecodedpayload()` was removed. To get similar functionality, pass the value 1 to the *decode* flag of the `get_payload()` method.
- The method `getpayloadastext()` was removed. Similar functionality is supported by the `DecodedGenerator` class in the `email.generator` module.
- The method `getbodyastext()` was removed. You can get similar functionality by creating an iterator with `typed_subpart_iterator()` in the `email.iterators` module.

The `Parser` class has no differences in its public interface. It does have some additional smarts to recognize *message/delivery-status* type messages, which it represents as a `Message` instance containing separate `Message` subparts for each header block in the delivery status notification<sup>7</sup>.

The `Generator` class has no differences in its public interface. There is a new class in the `email.generator` module though, called `DecodedGenerator` which provides most of the functionality previously available in the `Message.getpayloadastext()` method.

The following modules and classes have been changed:

- The `MIMEBase` class constructor arguments *\_major* and *\_minor* have changed to *\_maintype* and *\_subtype* respectively.
- The `Image` class/module has been renamed to `MIMEImage`. The *\_minor* argument has been renamed to *\_subtype*.
- The `Text` class/module has been renamed to `MIMEText`. The *\_minor* argument has been renamed to *\_subtype*.
- The `MessageRFC822` class/module has been renamed to `MIMEMessage`. Note that an earlier version of `mimelib` called this class/module `RFC822`, but that clashed with the Python standard library module `rfc822` on some case-insensitive file systems.

Also, the `MIMEMessage` class now represents any kind of MIME message with main type *message*. It takes an optional argument *\_subtype* which is used to set the MIME subtype. *\_subtype* defaults to *rfc822*.

<sup>7</sup> Delivery Status Notifications (DSN) are defined in [RFC 1894](#).

mimelib provided some utility functions in its `address` and `date` modules. All of these functions have been moved to the `email.utils` module.

The `MsgReader` class/module has been removed. Its functionality is most closely supported in the `body_line_iterator()` function in the `email.iterators` module.

## 18.2 json — JSON encoder and decoder

New in version 2.6. JSON (JavaScript Object Notation), specified by

**RFC 4627**, is a lightweight data interchange format based on a subset of JavaScript syntax (ECMA-262 3rd edition).

`json` exposes an API familiar to users of the standard library `marshal` and `pickle` modules.

Encoding basic Python object hierarchies:

```
>>> import json
>>> json.dumps(['foo', {'bar': ('baz', None, 1.0, 2)}])
'["foo", {"bar": ["baz", null, 1.0, 2]}]'
>>> print json.dumps("\"foo\\bar\"")
\"foo\\bar\"
>>> print json.dumps(u'\\u1234')
\"\\u1234\"
>>> print json.dumps('\\')
\"\\\"
>>> print json.dumps({'c': 0, 'b': 0, 'a': 0}, sort_keys=True)
{"a": 0, "b": 0, "c": 0}
>>> from StringIO import StringIO
>>> io = StringIO()
>>> json.dump(['streaming API'], io)
>>> io.getvalue()
'["streaming API"]'
```

Compact encoding:

```
>>> import json
>>> json.dumps([1,2,3,{'4': 5, '6': 7}], separators=(',', ':'))
'[1,2,3,{"4":5,"6":7}]'
```

Pretty printing:

```
>>> import json
>>> print json.dumps({'4': 5, '6': 7}, sort_keys=True, indent=4)
{
    "4": 5,
    "6": 7
}
```

Decoding JSON:

```
>>> import json
>>> json.loads('["foo", {"bar":["baz", null, 1.0, 2]}]')
[u'foo', {u'bar': [u'baz', None, 1.0, 2]}]
>>> json.loads('\"\\\"foo\\\"\\bar\"')
u'foo\x08ar'
>>> from StringIO import StringIO
>>> io = StringIO('["streaming API"]')
```

```
>>> json.load(io)
[u'streaming API']
```

Specializing JSON object decoding:

```
>>> import json
>>> def as_complex(dct):
...     if '__complex__' in dct:
...         return complex(dct['real'], dct['imag'])
...     return dct
...
>>> json.loads('{"__complex__": true, "real": 1, "imag": 2}',
...            object_hook=as_complex)
(1+2j)
>>> import decimal
>>> json.loads('1.1', parse_float=decimal.Decimal)
Decimal('1.1')
```

Extending JSONEncoder:

```
>>> import json
>>> class ComplexEncoder(json.JSONEncoder):
...     def default(self, obj):
...         if isinstance(obj, complex):
...             return [obj.real, obj.imag]
...         return json.JSONEncoder.default(self, obj)
...
>>> dumps(2 + 1j, cls=ComplexEncoder)
'[2.0, 1.0]'
>>> ComplexEncoder().encode(2 + 1j)
'[2.0, 1.0]'
>>> list(ComplexEncoder().iterencode(2 + 1j))
['[', '2.0', ',', '1.0', ']']
```

Using `json.tool` from the shell to validate and pretty-print:

```
$ echo '{"json":"obj"}' | python -mjson.tool
{
  "json": "obj"
}
$ echo '{1.2:3.4}' | python -mjson.tool
Expecting property name enclosed in double quotes: line 1 column 1 (char 1)
```

---

**Note:** JSON is a subset of [YAML 1.2](#). The JSON produced by this module's default settings (in particular, the default *separators* value) is also a subset of [YAML 1.0](#) and [1.1](#). This module can thus also be used as a [YAML](#) serializer.

---

## 18.2.1 Basic Usage

`json.dump(obj, fp[, skipkeys[, ensure_ascii[, check_circular[, allow_nan[, cls[, indent[, separators[, encoding[, default[, **kw]]]]]]]]])`  
 Serialize *obj* as a JSON formatted stream to *fp* (a `.write()`-supporting *file-like object*).

If *skipkeys* is `True` (default: `False`), then dict keys that are not of a basic type (`str`, `unicode`, `int`, `long`, `float`, `bool`, `None`) will be skipped instead of raising a `TypeError`.



can be used to implement custom decoders that rely on the order that the key and value pairs are decoded (for example, `collections.OrderedDict()` will remember the order of insertion). If `object_hook` is also defined, the `object_pairs_hook` takes priority. Changed in version 2.7: Added support for `object_pairs_hook`. `parse_float`, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON floats (e.g. `decimal.Decimal`).

`parse_int`, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. `float`).

`parse_constant`, if specified, will be called with one of the following strings: `'-Infinity'`, `'Infinity'`, `'NaN'`. This can be used to raise an exception if invalid JSON numbers are encountered. Changed in version 2.7: `parse_constant` doesn't get called on `'null'`, `'true'`, `'false'` anymore. To use a custom `JSONDecoder` subclass, specify it with the `cls` kwarg; otherwise `JSONDecoder` is used. Additional keyword arguments will be passed to the constructor of the class.

```
json.loads(s[, encoding[, cls[, object_hook[, parse_float[, parse_int[, parse_constant[, ob-
ject_pairs_hook[, **kw]]]]]]]]])
```

Deserialize *s* (a `str` or `unicode` instance containing a JSON document) to a Python object.

If *s* is a `str` instance and is encoded with an ASCII based encoding other than UTF-8 (e.g. latin-1), then an appropriate `encoding` name must be specified. Encodings that are not ASCII based (such as UCS-2) are not allowed and should be decoded to `unicode` first.

The other arguments have the same meaning as in `load()`.

## 18.2.2 Encoders and Decoders

```
class json.JSONDecoder([encoding[, object_hook[, parse_float[, parse_int[, parse_constant[, strict[,
object_pairs_hook]]]]]]])
```

Simple JSON decoder.

Performs the following translations in decoding by default:

JSON	Python
object	dict
array	list
string	unicode
number (int)	int, long
number (real)	float
true	True
false	False
null	None

It also understands `NaN`, `Infinity`, and `-Infinity` as their corresponding `float` values, which is outside the JSON spec.

`encoding` determines the encoding used to interpret any `str` objects decoded by this instance (UTF-8 by default). It has no effect when decoding `unicode` objects.

Note that currently only encodings that are a superset of ASCII work, strings of other encodings should be passed in as `unicode`.

`object_hook`, if specified, will be called with the result of every JSON object decoded and its return value will be used in place of the given `dict`. This can be used to provide custom deserializations (e.g. to support JSON-RPC class hinting).

*object\_pairs\_hook*, if specified will be called with the result of every JSON object decoded with an ordered list of pairs. The return value of *object\_pairs\_hook* will be used instead of the `dict`. This feature can be used to implement custom decoders that rely on the order that the key and value pairs are decoded (for example, `collections.OrderedDict()` will remember the order of insertion). If *object\_hook* is also defined, the *object\_pairs\_hook* takes priority. Changed in version 2.7: Added support for *object\_pairs\_hook*. *parse\_float*, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON floats (e.g. `decimal.Decimal`).

*parse\_int*, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. `float`).

*parse\_constant*, if specified, will be called with one of the following strings: `'-Infinity'`, `'Infinity'`, `'NaN'`, `'null'`, `'true'`, `'false'`. This can be used to raise an exception if invalid JSON numbers are encountered.

If *strict* is `False` (`True` is the default), then control characters will be allowed inside strings. Control characters in this context are those with character codes in the 0-31 range, including `'\t'` (tab), `'\n'`, `'\r'` and `'\0'`.

**decode** (*s*)

Return the Python representation of *s* (a `str` or `unicode` instance containing a JSON document)

**raw\_decode** (*s*)

Decode a JSON document from *s* (a `str` or `unicode` beginning with a JSON document) and return a 2-tuple of the Python representation and the index in *s* where the document ended.

This can be used to decode a JSON document from a string that may have extraneous data at the end.

```
class json.JSONEncoder ([skipkeys[, ensure_ascii[, check_circular[, allow_nan[, sort_keys[, indent[, separators[, encoding[, default ]]]]]]]]])
```

Extensible JSON encoder for Python data structures.

Supports the following objects and types by default:

Python	JSON
dict	object
list, tuple	array
str, unicode	string
int, long, float	number
True	true
False	false
None	null

To extend this to recognize other objects, subclass and implement a `default()` method with another method that returns a serializable object for `o` if possible, otherwise it should call the superclass implementation (to raise `TypeError`).

If *skipkeys* is `False` (the default), then it is a `TypeError` to attempt encoding of keys that are not `str`, `int`, `long`, `float` or `None`. If *skipkeys* is `True`, such items are simply skipped.

If *ensure\_ascii* is `True` (the default), all non-ASCII characters in the output are escaped with `\uXXXX` sequences, and the results are `str` instances consisting of ASCII characters only. If *ensure\_ascii* is `False`, a result may be a `unicode` instance. This usually happens if the input contains unicode strings or the *encoding* parameter is used.

If *check\_circular* is `True` (the default), then lists, dicts, and custom encoded objects will be checked for circular references during encoding to prevent an infinite recursion (which would cause an `OverflowError`). Otherwise, no such check takes place.

If `allow_nan` is `True` (the default), then `NaN`, `Infinity`, and `-Infinity` will be encoded as such. This behavior is not JSON specification compliant, but is consistent with most JavaScript based encoders and decoders. Otherwise, it will be a `ValueError` to encode such floats.

If `sort_keys` is `True` (default `False`), then the output of dictionaries will be sorted by key; this is useful for regression tests to ensure that JSON serializations can be compared on a day-to-day basis.

If `indent` is a non-negative integer (it is `None` by default), then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0 will only insert newlines. `None` is the most compact representation.

If specified, `separators` should be an `(item_separator, key_separator)` tuple. The default is `(' , ' , ' : ' )`. To get the most compact JSON representation, you should specify `(' , ' , ' : ' )` to eliminate whitespace.

If specified, `default` is a function that gets called for objects that can't otherwise be serialized. It should return a JSON encodable version of the object or raise a `TypeError`.

If `encoding` is not `None`, then all input strings will be transformed into unicode using that encoding prior to JSON-encoding. The default is UTF-8.

#### **default** (*o*)

Implement this method in a subclass such that it returns a serializable object for *o*, or calls the base implementation (to raise a `TypeError`).

For example, to support arbitrary iterators, you could implement `default` like this:

```
def default(self, o):
    try:
        iterable = iter(o)
    except TypeError:
        pass
    else:
        return list(iterable)
    return JSONEncoder.default(self, o)
```

#### **encode** (*o*)

Return a JSON string representation of a Python data structure, *o*. For example:

```
>>> JSONEncoder().encode({"foo": ["bar", "baz"]})
'{"foo": ["bar", "baz"]}'
```

#### **iterencode** (*o*)

Encode the given object, *o*, and yield each string representation as available. For example:

```
for chunk in JSONEncoder().iterencode(bigobject):
    mysocket.write(chunk)
```

## 18.2.3 Standard Compliance

The JSON format is specified by [RFC 4627](#). This section details this module's level of compliance with the RFC. For simplicity, `JSONEncoder` and `JSONDecoder` subclasses, and parameters other than those explicitly mentioned, are not considered.

This module does not comply with the RFC in a strict fashion, implementing some extensions that are valid JavaScript but not valid JSON. In particular:

- Top-level non-object, non-array values are accepted and output;

- Infinite and NaN number values are accepted and output;
- Repeated names within an object are accepted, and only the value of the last name-value pair is used.

Since the RFC permits RFC-compliant parsers to accept input texts that are not RFC-compliant, this module's deserializer is technically RFC-compliant under default settings.

### Character Encodings

The RFC recommends that JSON be represented using either UTF-8, UTF-16, or UTF-32, with UTF-8 being the default. Accordingly, this module uses UTF-8 as the default for its *encoding* parameter.

This module's deserializer only directly works with ASCII-compatible encodings; UTF-16, UTF-32, and other ASCII-incompatible encodings require the use of workarounds described in the documentation for the deserializer's *encoding* parameter.

The RFC also non-normatively describes a limited encoding detection technique for JSON texts; this module's deserializer does not implement this or any other kind of encoding detection.

As permitted, though not required, by the RFC, this module's serializer sets *ensure\_ascii=True* by default, thus escaping the output so that the resulting strings only contain ASCII characters.

### Top-level Non-Object, Non-Array Values

The RFC specifies that the top-level value of a JSON text must be either a JSON object or array (Python `dict` or `list`). This module's deserializer also accepts input texts consisting solely of a JSON null, boolean, number, or string value:

```
>>> just_a_json_string = '"spam and eggs"' # Not by itself a valid JSON text
>>> json.loads(just_a_json_string)
u'spam and eggs'
```

This module itself does not include a way to request that such input texts be regarded as illegal. Likewise, this module's serializer also accepts single Python `None`, `bool`, numeric, and `str` values as input and will generate output texts consisting solely of a top-level JSON null, boolean, number, or string value without raising an exception:

```
>>> neither_a_list_nor_a_dict = u"spam and eggs"
>>> json.dumps(neither_a_list_nor_a_dict) # The result is not a valid JSON text
'"spam and eggs"'
```

This module's serializer does not itself include a way to enforce the aforementioned constraint.

### Infinite and NaN Number Values

The RFC does not permit the representation of infinite or NaN number values. Despite that, by default, this module accepts and outputs `Infinity`, `-Infinity`, and `NaN` as if they were valid JSON number literal values:

```
>>> # Neither of these calls raises an exception, but the results are not valid JSON
>>> json.dumps(float('-inf'))
'-Infinity'
>>> json.dumps(float('nan'))
'NaN'
>>> # Same when deserializing
>>> json.loads('-Infinity')
-inf
>>> json.loads('NaN')
nan
```

In the serializer, the *allow\_nan* parameter can be used to alter this behavior. In the deserializer, the *parse\_constant* parameter can be used to alter this behavior.

### Repeated Names Within an Object

The RFC specifies that the names within a JSON object should be unique, but does not specify how repeated names in JSON objects should be handled. By default, this module does not raise an exception; instead, it ignores all but the last name-value pair for a given name:

```
>>> weird_json = '{"x": 1, "x": 2, "x": 3}'
>>> json.loads(weird_json)
{u'x': 3}
```

The *object\_pairs\_hook* parameter can be used to alter this behavior.

## 18.3 mailcap — Mailcap file handling

Source code: [Lib/mailcap.py](#)

Mailcap files are used to configure how MIME-aware applications such as mail readers and Web browsers react to files with different MIME types. (The name “mailcap” is derived from the phrase “mail capability”.) For example, a mailcap file might contain a line like `video/mpeg; xmpeg %s`. Then, if the user encounters an email message or Web document with the MIME type `video/mpeg`, `%s` will be replaced by a filename (usually one belonging to a temporary file) and the `xmpeg` program can be automatically started to view the file.

The mailcap format is documented in [RFC 1524](#), “A User Agent Configuration Mechanism For Multimedia Mail Format Information,” but is not an Internet standard. However, mailcap files are supported on most Unix systems.

`mailcap.findmatch(caps, MIMEtype[, key[, filename[, plist ] ] ])`

Return a 2-tuple; the first element is a string containing the command line to be executed (which can be passed to `os.system()`), and the second element is the mailcap entry for a given MIME type. If no matching MIME type can be found, `(None, None)` is returned.

*key* is the name of the field desired, which represents the type of activity to be performed; the default value is ‘view’, since in the most common case you simply want to view the body of the MIME-typed data. Other possible values might be ‘compose’ and ‘edit’, if you wanted to create a new body of the given MIME type or alter the existing body data. See [RFC 1524](#) for a complete list of these fields.

*filename* is the filename to be substituted for `%s` in the command line; the default value is `' /dev/null'` which is almost certainly not what you want, so usually you’ll override it by specifying a filename.

*plist* can be a list containing named parameters; the default value is simply an empty list. Each entry in the list must be a string containing the parameter name, an equals sign (`'='`), and the parameter’s value. Mailcap entries can contain named parameters like `%{foo}`, which will be replaced by the value of the parameter named ‘foo’. For example, if the command line `showpartial %{id} %{number} %{total}` was in a mailcap file, and *plist* was set to `['id=1', 'number=2', 'total=3']`, the resulting command line would be `'showpartial 1 2 3'`.

In a mailcap file, the “test” field can optionally be specified to test some external condition (such as the machine architecture, or the window system in use) to determine whether or not the mailcap line applies. `findmatch()` will automatically check such conditions and skip the entry if the check fails.

`mailcap.getcaps()`

Returns a dictionary mapping MIME types to a list of mailcap file entries. This dictionary must be passed to the

`findmatch()` function. An entry is stored as a list of dictionaries, but it shouldn't be necessary to know the details of this representation.

The information is derived from all of the mailcap files found on the system. Settings in the user's mailcap file `$HOME/.mailcap` will override settings in the system mailcap files `/etc/mailcap`, `/usr/etc/mailcap`, and `/usr/local/etc/mailcap`.

An example usage:

```
>>> import mailcap
>>> d=mailcap.getcaps()
>>> mailcap.findmatch(d, 'video/mpeg', filename='/tmp/tmp1223')
('xmpeg /tmp/tmp1223', {'view': 'xmpeg %s'})
```

## 18.4 mailbox — Manipulate mailboxes in various formats

This module defines two classes, `Mailbox` and `Message`, for accessing and manipulating on-disk mailboxes and the messages they contain. `Mailbox` offers a dictionary-like mapping from keys to messages. `Message` extends the `email.Message` module's `Message` class with format-specific state and behavior. Supported mailbox formats are Maildir, mbox, MH, Babyl, and MMDF.

**See Also:**

**Module `email`** Represent and manipulate messages.

### 18.4.1 Mailbox objects

**class `mailbox.Mailbox`**

A mailbox, which may be inspected and modified.

The `Mailbox` class defines an interface and is not intended to be instantiated. Instead, format-specific subclasses should inherit from `Mailbox` and your code should instantiate a particular subclass.

The `Mailbox` interface is dictionary-like, with small keys corresponding to messages. Keys are issued by the `Mailbox` instance with which they will be used and are only meaningful to that `Mailbox` instance. A key continues to identify a message even if the corresponding message is modified, such as by replacing it with another message.

Messages may be added to a `Mailbox` instance using the set-like method `add()` and removed using a `del` statement or the set-like methods `remove()` and `discard()`.

`Mailbox` interface semantics differ from dictionary semantics in some noteworthy ways. Each time a message is requested, a new representation (typically a `Message` instance) is generated based upon the current state of the mailbox. Similarly, when a message is added to a `Mailbox` instance, the provided message representation's contents are copied. In neither case is a reference to the message representation kept by the `Mailbox` instance.

The default `Mailbox` iterator iterates over message representations, not keys as the default dictionary iterator does. Moreover, modification of a mailbox during iteration is safe and well-defined. Messages added to the mailbox after an iterator is created will not be seen by the iterator. Messages removed from the mailbox before the iterator yields them will be silently skipped, though using a key from an iterator may result in a `KeyError` exception if the corresponding message is subsequently removed.

**Warning:** Be very cautious when modifying mailboxes that might be simultaneously changed by some other process. The safest mailbox format to use for such tasks is Maildir; try to avoid using single-file formats such as mbox for concurrent writing. If you're modifying a mailbox, you *must* lock it by calling the `lock()` and `unlock()` methods *before* reading any messages in the file or making any changes by adding or deleting a message. Failing to lock the mailbox runs the risk of losing messages or corrupting the entire mailbox.

`Mailbox` instances have the following methods:

**add** (*message*)

Add *message* to the mailbox and return the key that has been assigned to it.

Parameter *message* may be a `Message` instance, an `email.Message.Message` instance, a string, or a file-like object (which should be open in text mode). If *message* is an instance of the appropriate format-specific `Message` subclass (e.g., if it's an `mboxMessage` instance and this is an `mbox` instance), its format-specific information is used. Otherwise, reasonable defaults for format-specific information are used.

**remove** (*key*)

**\_\_delitem\_\_** (*key*)

**discard** (*key*)

Delete the message corresponding to *key* from the mailbox.

If no such message exists, a `KeyError` exception is raised if the method was called as `remove()` or `__delitem__()` but no exception is raised if the method was called as `discard()`. The behavior of `discard()` may be preferred if the underlying mailbox format supports concurrent modification by other processes.

**\_\_setitem\_\_** (*key, message*)

Replace the message corresponding to *key* with *message*. Raise a `KeyError` exception if no message already corresponds to *key*.

As with `add()`, parameter *message* may be a `Message` instance, an `email.Message.Message` instance, a string, or a file-like object (which should be open in text mode). If *message* is an instance of the appropriate format-specific `Message` subclass (e.g., if it's an `mboxMessage` instance and this is an `mbox` instance), its format-specific information is used. Otherwise, the format-specific information of the message that currently corresponds to *key* is left unchanged.

**iterkeys** ()

**keys** ()

Return an iterator over all keys if called as `iterkeys()` or return a list of keys if called as `keys()`.

**itervalues** ()

**\_\_iter\_\_** ()

**values** ()

Return an iterator over representations of all messages if called as `itervalues()` or `__iter__()` or return a list of such representations if called as `values()`. The messages are represented as instances of the appropriate format-specific `Message` subclass unless a custom message factory was specified when the `Mailbox` instance was initialized.

---

**Note:** The behavior of `__iter__()` is unlike that of dictionaries, which iterate over keys.

---

**iteritems** ()

**items** ()

Return an iterator over (*key, message*) pairs, where *key* is a key and *message* is a message representation, if called as `iteritems()` or return a list of such pairs if called as `items()`. The messages are represented

as instances of the appropriate format-specific `Message` subclass unless a custom message factory was specified when the `Mailbox` instance was initialized.

**get** (*key*, *default=None*)

**\_\_getitem\_\_** (*key*)

Return a representation of the message corresponding to *key*. If no such message exists, *default* is returned if the method was called as `get()` and a `KeyError` exception is raised if the method was called as `__getitem__()`. The message is represented as an instance of the appropriate format-specific `Message` subclass unless a custom message factory was specified when the `Mailbox` instance was initialized.

**get\_message** (*key*)

Return a representation of the message corresponding to *key* as an instance of the appropriate format-specific `Message` subclass, or raise a `KeyError` exception if no such message exists.

**get\_string** (*key*)

Return a string representation of the message corresponding to *key*, or raise a `KeyError` exception if no such message exists.

**get\_file** (*key*)

Return a file-like representation of the message corresponding to *key*, or raise a `KeyError` exception if no such message exists. The file-like object behaves as if open in binary mode. This file should be closed once it is no longer needed.

---

**Note:** Unlike other representations of messages, file-like representations are not necessarily independent of the `Mailbox` instance that created them or of the underlying mailbox. More specific documentation is provided by each subclass.

---

**has\_key** (*key*)

**\_\_contains\_\_** (*key*)

Return `True` if *key* corresponds to a message, `False` otherwise.

**\_\_len\_\_** ()

Return a count of messages in the mailbox.

**clear** ()

Delete all messages from the mailbox.

**pop** (*key*[, *default* ])

Return a representation of the message corresponding to *key* and delete the message. If no such message exists, return *default* if it was supplied or else raise a `KeyError` exception. The message is represented as an instance of the appropriate format-specific `Message` subclass unless a custom message factory was specified when the `Mailbox` instance was initialized.

**popitem** ()

Return an arbitrary (*key*, *message*) pair, where *key* is a key and *message* is a message representation, and delete the corresponding message. If the mailbox is empty, raise a `KeyError` exception. The message is represented as an instance of the appropriate format-specific `Message` subclass unless a custom message factory was specified when the `Mailbox` instance was initialized.

**update** (*arg*)

Parameter *arg* should be a *key-to-message* mapping or an iterable of (*key*, *message*) pairs. Updates the mailbox so that, for each given *key* and *message*, the message corresponding to *key* is set to *message* as if by using `__setitem__()`. As with `__setitem__()`, each *key* must already correspond to a message in the mailbox or else a `KeyError` exception will be raised, so in general it is incorrect for *arg* to be a `Mailbox` instance.

---

---

**Note:** Unlike with dictionaries, keyword arguments are not supported.

---

**flush()**

Write any pending changes to the filesystem. For some `Mailbox` subclasses, changes are always written immediately and `flush()` does nothing, but you should still make a habit of calling this method.

**lock()**

Acquire an exclusive advisory lock on the mailbox so that other processes know not to modify it. An `ExternalClashError` is raised if the lock is not available. The particular locking mechanisms used depend upon the mailbox format. You should *always* lock the mailbox before making any modifications to its contents.

**unlock()**

Release the lock on the mailbox, if any.

**close()**

Flush the mailbox, unlock it if necessary, and close any open files. For some `Mailbox` subclasses, this method does nothing.

**Maildir**

**class** `mailbox.Maildir` (*dirname*, *factory=rfc822.Message*, *create=True*)

A subclass of `Mailbox` for mailboxes in Maildir format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, `MaildirMessage` is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

It is for historical reasons that *factory* defaults to `rfc822.Message` and that *dirname* is named as such rather than *path*. For a `Maildir` instance that behaves like instances of other `Mailbox` subclasses, set *factory* to `None`.

Maildir is a directory-based mailbox format invented for the qmail mail transfer agent and now widely supported by other programs. Messages in a Maildir mailbox are stored in separate files within a common directory structure. This design allows Maildir mailboxes to be accessed and modified by multiple unrelated programs without data corruption, so file locking is unnecessary.

Maildir mailboxes contain three subdirectories, namely: `tmp`, `new`, and `cur`. Messages are created momentarily in the `tmp` subdirectory and then moved to the `new` subdirectory to finalize delivery. A mail user agent may subsequently move the message to the `cur` subdirectory and store information about the state of the message in a special “info” section appended to its file name.

Folders of the style introduced by the Courier mail transfer agent are also supported. Any subdirectory of the main mailbox is considered a folder if `'.'` is the first character in its name. Folder names are represented by `Maildir` without the leading `'.'`. Each folder is itself a Maildir mailbox but should not contain other folders. Instead, a logical nesting is indicated using `'.'` to delimit levels, e.g., “Archived.2005.07”.

---

**Note:** The Maildir specification requires the use of a colon (`:`) in certain message file names. However, some operating systems do not permit this character in file names. If you wish to use a Maildir-like format on such an operating system, you should specify another character to use instead. The exclamation point (`!`) is a popular choice. For example:

```
import mailbox
mailbox.Maildir.colon = '!'
```

The `colon` attribute may also be set on a per-instance basis.

---

`Maildir` instances have all of the methods of `Mailbox` in addition to the following:

**list\_folders** ()

Return a list of the names of all folders.

**get\_folder** (*folder*)

Return a `Maildir` instance representing the folder whose name is *folder*. A `NoSuchMailboxError` exception is raised if the folder does not exist.

**add\_folder** (*folder*)

Create a folder whose name is *folder* and return a `Maildir` instance representing it.

**remove\_folder** (*folder*)

Delete the folder whose name is *folder*. If the folder contains any messages, a `NotEmptyError` exception will be raised and the folder will not be deleted.

**clean** ()

Delete temporary files from the mailbox that have not been accessed in the last 36 hours. The `Maildir` specification says that mail-reading programs should do this occasionally.

Some `Mailbox` methods implemented by `Maildir` deserve special remarks:

**add** (*message*)

**\_\_getitem\_\_** (*key*, *message*)

**update** (*arg*)

<p><b>Warning:</b> These methods generate unique file names based upon the current process ID. When using multiple threads, undetected name clashes may occur and cause corruption of the mailbox unless threads are coordinated to avoid using these methods to manipulate the same mailbox simultaneously.</p>
--

**flush** ()

All changes to `Maildir` mailboxes are immediately applied, so this method does nothing.

**lock** ()

**unlock** ()

`Maildir` mailboxes do not support (or require) locking, so these methods do nothing.

**close** ()

`Maildir` instances do not keep any open files and the underlying mailboxes do not support locking, so this method does nothing.

**get\_file** (*key*)

Depending upon the host platform, it may not be possible to modify or remove the underlying message while the returned file remains open.

**See Also:**

**maildir man page from gmail** The original specification of the format.

**Using maildir format** Notes on `Maildir` by its inventor. Includes an updated name-creation scheme and details on “info” semantics.

**maildir man page from Courier** Another specification of the format. Describes a common extension for supporting folders.

**mbox**

**class mailbox.mbox** (*path*, *factory=None*, *create=True*)

A subclass of `Mailbox` for mailboxes in `mbox` format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If

*factory* is `None`, `mboxMessage` is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

The `mbox` format is the classic format for storing mail on Unix systems. All messages in an `mbox` mailbox are stored in a single file with the beginning of each message indicated by a line whose first five characters are “From ”.

Several variations of the `mbox` format exist to address perceived shortcomings in the original. In the interest of compatibility, `mbox` implements the original format, which is sometimes referred to as *mboxo*. This means that the `Content-Length` header, if present, is ignored and that any occurrences of “From ” at the beginning of a line in a message body are transformed to “>From ” when storing the message, although occurrences of “>From ” are not transformed to “From ” when reading the message.

Some `Mailbox` methods implemented by `mbox` deserve special remarks:

**get\_file** (*key*)

Using the file after calling `flush()` or `close()` on the `mbox` instance may yield unpredictable results or raise an exception.

**lock** ()

**unlock** ()

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

#### See Also:

**mbox man page from qmail** A specification of the format and its variations.

**mbox man page from tin** Another specification of the format, with details on locking.

**Configuring Netscape Mail on Unix: Why The Content-Length Format is Bad** An argument for using the original `mbox` format rather than a variation.

**“mbox” is a family of several mutually incompatible mailbox formats** A history of `mbox` variations.

## MH

**class** `mailbox.MH` (*path*, *factory=None*, *create=True*)

A subclass of `Mailbox` for mailboxes in MH format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, `MHMessage` is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

MH is a directory-based mailbox format invented for the MH Message Handling System, a mail user agent. Each message in an MH mailbox resides in its own file. An MH mailbox may contain other MH mailboxes (called *folders*) in addition to messages. Folders may be nested indefinitely. MH mailboxes also support *sequences*, which are named lists used to logically group messages without moving them to sub-folders. Sequences are defined in a file called `.mh_sequences` in each folder.

The `MH` class manipulates MH mailboxes, but it does not attempt to emulate all of `mh`'s behaviors. In particular, it does not modify and is not affected by the `context` or `.mh_profile` files that are used by `mh` to store its state and configuration.

`MH` instances have all of the methods of `Mailbox` in addition to the following:

**list\_folders** ()

Return a list of the names of all folders.

**get\_folder** (*folder*)

Return an `MH` instance representing the folder whose name is *folder*. A `NoSuchMailboxError` exception is raised if the folder does not exist.

**add\_folder** (*folder*)

Create a folder whose name is *folder* and return an `MH` instance representing it.

**remove\_folder** (*folder*)

Delete the folder whose name is *folder*. If the folder contains any messages, a `NotEmptyError` exception will be raised and the folder will not be deleted.

**get\_sequences** ()

Return a dictionary of sequence names mapped to key lists. If there are no sequences, the empty dictionary is returned.

**set\_sequences** (*sequences*)

Re-define the sequences that exist in the mailbox based upon *sequences*, a dictionary of names mapped to key lists, like returned by `get_sequences()`.

**pack** ()

Rename messages in the mailbox as necessary to eliminate gaps in numbering. Entries in the sequences list are updated correspondingly.

---

**Note:** Already-issued keys are invalidated by this operation and should not be subsequently used.

---

Some `Mailbox` methods implemented by `MH` deserve special remarks:

**remove** (*key*)

**\_\_delitem\_\_** (*key*)

**discard** (*key*)

These methods immediately delete the message. The `MH` convention of marking a message for deletion by prepending a comma to its name is not used.

**lock** ()

**unlock** ()

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls. For `MH` mailboxes, locking the mailbox means locking the `.mh_sequences` file and, only for the duration of any operations that affect them, locking individual message files.

**get\_file** (*key*)

Depending upon the host platform, it may not be possible to remove the underlying message while the returned file remains open.

**flush** ()

All changes to `MH` mailboxes are immediately applied, so this method does nothing.

**close** ()

`MH` instances do not keep any open files, so this method is equivalent to `unlock()`.

**See Also:**

**[nmh - Message Handling System](#)** Home page of `nmh`, an updated version of the original `mh`.

**[MH & nmh: Email for Users & Programmers](#)** A GPL-licensed book on `mh` and `nmh`, with some information on the mailbox format.

**Babyl**

**class** `mailbox.Babyl` (*path*, *factory=None*, *create=True*)

A subclass of `Mailbox` for mailboxes in Babyl format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, `BabylMessage` is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

Babyl is a single-file mailbox format used by the Rmail mail user agent included with Emacs. The beginning of a message is indicated by a line containing the two characters Control-Underscore (`'\037'`) and Control-L (`'\014'`). The end of a message is indicated by the start of the next message or, in the case of the last message, a line containing a Control-Underscore (`'\037'`) character.

Messages in a Babyl mailbox have two sets of headers, original headers and so-called visible headers. Visible headers are typically a subset of the original headers that have been reformatted or abridged to be more attractive. Each message in a Babyl mailbox also has an accompanying list of *labels*, or short strings that record extra information about the message, and a list of all user-defined labels found in the mailbox is kept in the Babyl options section.

`Babyl` instances have all of the methods of `Mailbox` in addition to the following:

**`get_labels()`**

Return a list of the names of all user-defined labels used in the mailbox.

---

**Note:** The actual messages are inspected to determine which labels exist in the mailbox rather than consulting the list of labels in the Babyl options section, but the Babyl section is updated whenever the mailbox is modified.

---

Some `Mailbox` methods implemented by `Babyl` deserve special remarks:

**`get_file(key)`**

In Babyl mailboxes, the headers of a message are not stored contiguously with the body of the message. To generate a file-like representation, the headers and body are copied together into a `StringIO` instance (from the `StringIO` module), which has an API identical to that of a file. As a result, the file-like object is truly independent of the underlying mailbox but does not save memory compared to a string representation.

**`lock()`**

**`unlock()`**

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

**See Also:**

**Format of Version 5 Babyl Files** A specification of the Babyl format.

**Reading Mail with Rmail** The Rmail manual, with some information on Babyl semantics.

**MMDF**

**`class mailbox.MMDF(path, factory=None, create=True)`**

A subclass of `Mailbox` for mailboxes in MMDF format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, `MMDFMessage` is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

MMDF is a single-file mailbox format invented for the Multichannel Memorandum Distribution Facility, a mail transfer agent. Each message is in the same form as an mbox message but is bracketed before and after by lines containing four Control-A (`'\001'`) characters. As with the mbox format, the beginning of each message is indicated by a line whose first five characters are “From”, but additional occurrences of “From” are not transformed to “>From” when storing messages because the extra message separator lines prevent mistaking such occurrences for the starts of subsequent messages.

Some `Mailbox` methods implemented by `MMDF` deserve special remarks:

**get\_file** (*key*)

Using the file after calling `flush()` or `close()` on the `MMDF` instance may yield unpredictable results or raise an exception.

**lock** ()

**unlock** ()

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

**See Also:**

**mmdf man page from tin** A specification of MMDF format from the documentation of tin, a newsreader.

**MMDF** A Wikipedia article describing the Multichannel Memorandum Distribution Facility.

## 18.4.2 Message objects

**class** `mailbox.Message` (*[message]*)

A subclass of the `email.Message` module's `Message`. Subclasses of `mailbox.Message` add mailbox-format-specific state and behavior.

If *message* is omitted, the new instance is created in a default, empty state. If *message* is an `email.Message.Message` instance, its contents are copied; furthermore, any format-specific information is converted insofar as possible if *message* is a `Message` instance. If *message* is a string or a file, it should contain an [RFC 2822](#)-compliant message, which is read and parsed.

The format-specific state and behaviors offered by subclasses vary, but in general it is only the properties that are not specific to a particular mailbox that are supported (although presumably the properties are specific to a particular mailbox format). For example, file offsets for single-file mailbox formats and file names for directory-based mailbox formats are not retained, because they are only applicable to the original mailbox. But state such as whether a message has been read by the user or marked as important is retained, because it applies to the message itself.

There is no requirement that `Message` instances be used to represent messages retrieved using `Mailbox` instances. In some situations, the time and memory required to generate `Message` representations might not be acceptable. For such situations, `Mailbox` instances also offer string and file-like representations, and a custom message factory may be specified when a `Mailbox` instance is initialized.

### **MaildirMessage**

**class** `mailbox.MaildirMessage` (*[message]*)

A message with Maildir-specific behaviors. Parameter *message* has the same meaning as with the `Message` constructor.

Typically, a mail user agent application moves all of the messages in the `new` subdirectory to the `cur` subdirectory after the first time the user opens and closes the mailbox, recording that the messages are old whether or not they've actually been read. Each message in `cur` has an “info” section added to its file name to store information about its state. (Some mail readers may also add an “info” section to messages in `new`.) The “info” section may take one of two forms: it may contain “2,” followed by a list of standardized flags (e.g., “2,FR”) or it may contain “1,” followed by so-called experimental information. Standard flags for Maildir messages are as follows:

Flag	Meaning	Explanation
D	Draft	Under composition
F	Flagged	Marked as important
P	Passed	Forwarded, resent, or bounced
R	Replied	Replied to
S	Seen	Read
T	Trashed	Marked for subsequent deletion

`MaildirMessage` instances offer the following methods:

**get\_subdir** ()

Return either “new” (if the message should be stored in the `new` subdirectory) or “cur” (if the message should be stored in the `cur` subdirectory).

---

**Note:** A message is typically moved from `new` to `cur` after its mailbox has been accessed, whether or not the message is has been read. A message `msg` has been read if “S” in `msg.get_flags()` is `True`.

---

**set\_subdir** (*subdir*)

Set the subdirectory the message should be stored in. Parameter *subdir* must be either “new” or “cur”.

**get\_flags** ()

Return a string specifying the flags that are currently set. If the message complies with the standard Maildir format, the result is the concatenation in alphabetical order of zero or one occurrence of each of ‘D’, ‘F’, ‘P’, ‘R’, ‘S’, and ‘T’. The empty string is returned if no flags are set or if “info” contains experimental semantics.

**set\_flags** (*flags*)

Set the flags specified by *flags* and unset all others.

**add\_flag** (*flag*)

Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character. The current “info” is overwritten whether or not it contains experimental information rather than flags.

**remove\_flag** (*flag*)

Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character. If “info” contains experimental information rather than flags, the current “info” is not modified.

**get\_date** ()

Return the delivery date of the message as a floating-point number representing seconds since the epoch.

**set\_date** (*date*)

Set the delivery date of the message to *date*, a floating-point number representing seconds since the epoch.

**get\_info** ()

Return a string containing the “info” for a message. This is useful for accessing and modifying “info” that is experimental (i.e., not a list of flags).

**set\_info** (*info*)

Set “info” to *info*, which should be a string.

When a `MaildirMessage` instance is created based upon an `mboxMessage` or `MMDFMessage` instance, the `Status` and `X-Status` headers are omitted and the following conversions take place:

Resulting state	<code>mboxMessage</code> or <code>MMDFMessage</code> state
“cur” subdirectory	O flag
F flag	F flag
R flag	A flag
S flag	R flag
T flag	D flag

When a `MaildirMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

Resulting state	<code>MHMessage</code> state
“cur” subdirectory	“unseen” sequence
“cur” subdirectory and S flag	no “unseen” sequence
F flag	“flagged” sequence
R flag	“replied” sequence

When a `MaildirMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

Resulting state	<code>BabylMessage</code> state
“cur” subdirectory	“unseen” label
“cur” subdirectory and S flag	no “unseen” label
P flag	“forwarded” or “resent” label
R flag	“answered” label
T flag	“deleted” label

### `mboxMessage`

`class mailbox.mboxMessage([message])`

A message with mbox-specific behaviors. Parameter `message` has the same meaning as with the `Message` constructor.

Messages in an mbox mailbox are stored together in a single file. The sender’s envelope address and the time of delivery are typically stored in a line beginning with “From ” that is used to indicate the start of a message, though there is considerable variation in the exact format of this data among mbox implementations. Flags that indicate the state of the message, such as whether it has been read or marked as important, are typically stored in `Status` and `X-Status` headers.

Conventional flags for mbox messages are as follows:

Flag	Meaning	Explanation
R	Read	Read
O	Old	Previously detected by MUA
D	Deleted	Marked for subsequent deletion
F	Flagged	Marked as important
A	Answered	Replied to

The “R” and “O” flags are stored in the `Status` header, and the “D”, “F”, and “A” flags are stored in the `X-Status` header. The flags and headers typically appear in the order mentioned.

`mboxMessage` instances offer the following methods:

`get_from()`

Return a string representing the “From ” line that marks the start of the message in an mbox mailbox. The leading “From ” and the trailing newline are excluded.

`set_from(from_, time_=None)`

Set the “From ” line to `from_`, which should be specified without a leading “From ” or trailing newline. For

convenience, *time\_* may be specified and will be formatted appropriately and appended to *from\_*. If *time\_* is specified, it should be a `struct_time` instance, a tuple suitable for passing to `time.strftime()`, or `True` (to use `time.gmtime()`).

**get\_flags()**

Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of 'R', 'O', 'D', 'F', and 'A'.

**set\_flags(*flags*)**

Set the flags specified by *flags* and unset all others. Parameter *flags* should be the concatenation in any order of zero or more occurrences of each of 'R', 'O', 'D', 'F', and 'A'.

**add\_flag(*flag*)**

Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character.

**remove\_flag(*flag*)**

Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character.

When an `mbxMessage` instance is created based upon a `MaildirMessage` instance, a “From ” line is generated based upon the `MaildirMessage` instance’s delivery date, and the following conversions take place:

Resulting state	MaildirMessage state
R flag	S flag
O flag	“cur” subdirectory
D flag	T flag
F flag	F flag
A flag	R flag

When an `mbxMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

Resulting state	MHMessage state
R flag and O flag	no “unseen” sequence
O flag	“unseen” sequence
F flag	“flagged” sequence
A flag	“replied” sequence

When an `mbxMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

Resulting state	BabylMessage state
R flag and O flag	no “unseen” label
O flag	“unseen” label
D flag	“deleted” label
A flag	“answered” label

When a `Message` instance is created based upon an `MMDFMessage` instance, the “From ” line is copied and all flags directly correspond:

Resulting state	MMDFMessage state
R flag	R flag
O flag	O flag
D flag	D flag
F flag	F flag
A flag	A flag

## MHMessage

**class** mailbox.**MHMessage** (*[message]*)

A message with MH-specific behaviors. Parameter *message* has the same meaning as with the `Message` constructor.

MH messages do not support marks or flags in the traditional sense, but they do support sequences, which are logical groupings of arbitrary messages. Some mail reading programs (although not the standard `mh` and `nmh`) use sequences in much the same way flags are used with other formats, as follows:

Sequence	Explanation
unseen	Not read, but previously detected by MUA
replied	Replied to
flagged	Marked as important

`MHMessage` instances offer the following methods:

**get\_sequences** ()

Return a list of the names of sequences that include this message.

**set\_sequences** (*sequences*)

Set the list of sequences that include this message.

**add\_sequence** (*sequence*)

Add *sequence* to the list of sequences that include this message.

**remove\_sequence** (*sequence*)

Remove *sequence* from the list of sequences that include this message.

When an `MHMessage` instance is created based upon a `MaildirMessage` instance, the following conversions take place:

Resulting state	MaildirMessage state
“unseen” sequence	no S flag
“replied” sequence	R flag
“flagged” sequence	F flag

When an `MHMessage` instance is created based upon an `mboxMessage` or `MMDFMessage` instance, the `Status` and `X-Status` headers are omitted and the following conversions take place:

Resulting state	mboxMessage or MMDFMessage state
“unseen” sequence	no R flag
“replied” sequence	A flag
“flagged” sequence	F flag

When an `MHMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

Resulting state	BabylMessage state
“unseen” sequence	“unseen” label
“replied” sequence	“answered” label

## BabylMessage

**class** mailbox.**BabylMessage** (*[message]*)

A message with Babyl-specific behaviors. Parameter *message* has the same meaning as with the `Message` constructor.

Certain message labels, called *attributes*, are defined by convention to have special meanings. The attributes are as follows:

Label	Explanation
unseen	Not read, but previously detected by MUA
deleted	Marked for subsequent deletion
filed	Copied to another file or mailbox
answered	Replied to
forwarded	Forwarded
edited	Modified by the user
resent	Resent

By default, Rmail displays only visible headers. The `BabylMessage` class, though, uses the original headers because they are more complete. Visible headers may be accessed explicitly if desired.

`BabylMessage` instances offer the following methods:

**get\_labels** ()

Return a list of labels on the message.

**set\_labels** (*labels*)

Set the list of labels on the message to *labels*.

**add\_label** (*label*)

Add *label* to the list of labels on the message.

**remove\_label** (*label*)

Remove *label* from the list of labels on the message.

**get\_visible** ()

Return an `Message` instance whose headers are the message's visible headers and whose body is empty.

**set\_visible** (*visible*)

Set the message's visible headers to be the same as the headers in *message*. Parameter *visible* should be a `Message` instance, an `email.Message.Message` instance, a string, or a file-like object (which should be open in text mode).

**update\_visible** ()

When a `BabylMessage` instance's original headers are modified, the visible headers are not automatically modified to correspond. This method updates the visible headers as follows: each visible header with a corresponding original header is set to the value of the original header, each visible header without a corresponding original header is removed, and any of *Date*, *From*, *Reply-To*, *To*, *CC*, and *Subject* that are present in the original headers but not the visible headers are added to the visible headers.

When a `BabylMessage` instance is created based upon a `MaildirMessage` instance, the following conversions take place:

Resulting state	MaildirMessage state
"unseen" label	no S flag
"deleted" label	T flag
"answered" label	R flag
"forwarded" label	P flag

When a `BabylMessage` instance is created based upon an `mboxMessage` or `MMDFMessage` instance, the *Status* and *X-Status* headers are omitted and the following conversions take place:

Resulting state	mboxMessage or MMDFMessage state
"unseen" label	no R flag
"deleted" label	D flag
"answered" label	A flag

When a `BabylMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

Resulting state	MHMessage state
“unseen” label	“unseen” sequence
“answered” label	“replied” sequence

### MMDFMessage

**class** mailbox.MMDFMessage (*[message]*)

A message with MMDF-specific behaviors. Parameter *message* has the same meaning as with the [Message](#) constructor.

As with *message* in an mbox mailbox, MMDF messages are stored with the sender’s address and the delivery date in an initial line beginning with “From”. Likewise, flags that indicate the state of the message are typically stored in *Status* and *X-Status* headers.

Conventional flags for MMDF messages are identical to those of mbox message and are as follows:

Flag	Meaning	Explanation
R	Read	Read
O	Old	Previously detected by MUA
D	Deleted	Marked for subsequent deletion
F	Flagged	Marked as important
A	Answered	Replied to

The “R” and “O” flags are stored in the *Status* header, and the “D”, “F”, and “A” flags are stored in the *X-Status* header. The flags and headers typically appear in the order mentioned.

MMDFMessage instances offer the following methods, which are identical to those offered by [mboxMessage](#):

**get\_from()**

Return a string representing the “From” line that marks the start of the message in an mbox mailbox. The leading “From” and the trailing newline are excluded.

**set\_from(*from\_*, *time\_=None*)**

Set the “From” line to *from\_*, which should be specified without a leading “From” or trailing newline. For convenience, *time\_* may be specified and will be formatted appropriately and appended to *from\_*. If *time\_* is specified, it should be a `struct_time` instance, a tuple suitable for passing to `time.strftime()`, or `True` (to use `time.gmtime()`).

**get\_flags()**

Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of ‘R’, ‘O’, ‘D’, ‘F’, and ‘A’.

**set\_flags(*flags*)**

Set the flags specified by *flags* and unset all others. Parameter *flags* should be the concatenation in any order of zero or more occurrences of each of ‘R’, ‘O’, ‘D’, ‘F’, and ‘A’.

**add\_flag(*flag*)**

Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character.

**remove\_flag(*flag*)**

Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* may be a string of more than one character.

When an MMDFMessage instance is created based upon a MaildirMessage instance, a “From” line is generated based upon the MaildirMessage instance’s delivery date, and the following conversions take place:

Resulting state	MaildirMessage state
R flag	S flag
O flag	“cur” subdirectory
D flag	T flag
F flag	F flag
A flag	R flag

When an `MMDFMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

Resulting state	MHMessage state
R flag and O flag	no “unseen” sequence
O flag	“unseen” sequence
F flag	“flagged” sequence
A flag	“replied” sequence

When an `MMDFMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

Resulting state	BabylMessage state
R flag and O flag	no “unseen” label
O flag	“unseen” label
D flag	“deleted” label
A flag	“answered” label

When an `MMDFMessage` instance is created based upon an `mboxMessage` instance, the “From ” line is copied and all flags directly correspond:

Resulting state	mboxMessage state
R flag	R flag
O flag	O flag
D flag	D flag
F flag	F flag
A flag	A flag

### 18.4.3 Exceptions

The following exception classes are defined in the `mailbox` module:

**exception** `mailbox.Error`

The based class for all other module-specific exceptions.

**exception** `mailbox.NoSuchMailboxError`

Raised when a mailbox is expected but is not found, such as when instantiating a `Mailbox` subclass with a path that does not exist (and with the `create` parameter set to `False`), or when opening a folder that does not exist.

**exception** `mailbox.NotEmptyError`

Raised when a mailbox is not empty but is expected to be, such as when deleting a folder that contains messages.

**exception** `mailbox.ExternalClashError`

Raised when some mailbox-related condition beyond the control of the program causes it to be unable to proceed, such as when failing to acquire a lock that another program already holds a lock, or when a uniquely-generated file name already exists.

**exception** `mailbox.FormatError`

Raised when the data in a file cannot be parsed, such as when an `MH` instance attempts to read a corrupted `.mh_sequences` file.

## 18.4.4 Deprecated classes and methods

Deprecated since version 2.6. Older versions of the `mailbox` module do not support modification of mailboxes, such as adding or removing message, and do not provide classes to represent format-specific message properties. For backward compatibility, the older mailbox classes are still available, but the newer classes should be used in preference to them. The old classes have been removed in Python 3.

Older mailbox objects support only iteration and provide a single public method:

`oldmailbox.next()`

Return the next message in the mailbox, created with the optional *factory* argument passed into the mailbox object's constructor. By default this is an `rfc822.Message` object (see the `rfc822` module). Depending on the mailbox implementation the *fp* attribute of this object may be a true file object or a class instance simulating a file object, taking care of things like message boundaries if multiple mail messages are contained in a single file, etc. If no more messages are available, this method returns `None`.

Most of the older mailbox classes have names that differ from the current mailbox class names, except for `Mailydir`. For this reason, the new `Mailydir` class defines a `next()` method and its constructor differs slightly from those of the other new mailbox classes.

The older mailbox classes whose names are not the same as their newer counterparts are as follows:

**class** `mailbox.UnixMailbox` (*fp*[, *factory* ])

Access to a classic Unix-style mailbox, where all messages are contained in a single file and separated by `From` (a.k.a. `From_`) lines. The file object *fp* points to the mailbox file. The optional *factory* parameter is a callable that should create new message objects. *factory* is called with one argument, *fp* by the `next()` method of the mailbox object. The default is the `rfc822.Message` class (see the `rfc822` module – and the note below).

---

**Note:** For reasons of this module's internal implementation, you will probably want to open the *fp* object in binary mode. This is especially important on Windows.

---

For maximum portability, messages in a Unix-style mailbox are separated by any line that begins exactly with the string `'From '` (note the trailing space) if preceded by exactly two newlines. Because of the wide-range of variations in practice, nothing else on the `From_` line should be considered. However, the current implementation doesn't check for the leading two newlines. This is usually fine for most applications.

The `UnixMailbox` class implements a more strict version of `From_` line checking, using a regular expression that usually correctly matched `From_` delimiters. It considers delimiter line to be separated by `From name time` lines. For maximum portability, use the `PortableUnixMailbox` class instead. This class is identical to `UnixMailbox` except that individual messages are separated by only `From` lines.

**class** `mailbox.PortableUnixMailbox` (*fp*[, *factory* ])

A less-strict version of `UnixMailbox`, which considers only the `From` at the beginning of the line separating messages. The “*name time*” portion of the `From` line is ignored, to protect against some variations that are observed in practice. This works since lines in the message which begin with `'From '` are quoted by mail handling software at delivery-time.

**class** `mailbox.MmdfMailbox` (*fp*[, *factory* ])

Access an MMDF-style mailbox, where all messages are contained in a single file and separated by lines consisting of 4 control-A characters. The file object *fp* points to the mailbox file. Optional *factory* is as with the `UnixMailbox` class.

**class** `mailbox.MHMailbox` (*dirname*[, *factory* ])

Access an MH mailbox, a directory with each message in a separate file with a numeric name. The name of the mailbox directory is passed in *dirname*. *factory* is as with the `UnixMailbox` class.

**class** `mailbox.BabylMailbox` (*fp*[, *factory* ])

Access a Babyl mailbox, which is similar to an MMDF mailbox. In Babyl format, each message has two sets

of headers, the *original* headers and the *visible* headers. The original headers appear before a line containing only '\*\*\* EOOH \*\*\*' (End-Of-Original-Headers) and the visible headers appear after the EOOH line. Babyl-compliant mail readers will show you only the visible headers, and `BabylMailbox` objects will return messages containing only the visible headers. You'll have to do your own parsing of the mailbox file to get at the original headers. Mail messages start with the EOOH line and end with a line containing only '\037\014'. `factory` is as with the `UnixMailbox` class.

If you wish to use the older mailbox classes with the `email` module rather than the deprecated `rfc822` module, you can do so as follows:

```
import email
import email.Errors
import mailbox

def msgfactory(fp):
    try:
        return email.message_from_file(fp)
    except email.Errors.MessageParseError:
        # Don't return None since that will
        # stop the mailbox iterator
        return ''
```

```
mbox = mailbox.UnixMailbox(fp, msgfactory)
```

Alternatively, if you know your mailbox contains only well-formed MIME messages, you can simplify this to:

```
import email
import mailbox

mbox = mailbox.UnixMailbox(fp, email.message_from_file)
```

## 18.4.5 Examples

A simple example of printing the subjects of all messages in a mailbox that seem interesting:

```
import mailbox
for message in mailbox.mbox('~/.mbox'):
    subject = message['subject'] # Could possibly be None.
    if subject and 'python' in subject.lower():
        print subject
```

To copy all mail from a Babyl mailbox to an MH mailbox, converting all of the format-specific information that can be converted:

```
import mailbox
destination = mailbox.MH('~/.Mail')
destination.lock()
for message in mailbox.Babyl('~/.RMAIL'):
    destination.add(mailbox.MHMessage(message))
destination.flush()
destination.unlock()
```

This example sorts mail from several mailing lists into different mailboxes, being careful to avoid mail corruption due to concurrent modification by other programs, mail loss due to interruption of the program, or premature termination due to malformed messages in the mailbox:

```
import mailbox
import email.Errors
```

```
list_names = ('python-list', 'python-dev', 'python-bugs')

boxes = dict((name, mailbox.mbox('~/%s' % name)) for name in list_names)
inbox = mailbox.Maildir('~/Maildir', factory=None)

for key in inbox.iterkeys():
    try:
        message = inbox[key]
    except email.Errors.MessageParseError:
        continue          # The message is malformed. Just leave it.

    for name in list_names:
        list_id = message['list-id']
        if list_id and name in list_id:
            # Get mailbox to use
            box = boxes[name]

            # Write copy to disk before removing original.
            # If there's a crash, you might duplicate a message, but
            # that's better than losing a message completely.
            box.lock()
            box.add(message)
            box.flush()
            box.unlock()

            # Remove original message
            inbox.lock()
            inbox.discard(key)
            inbox.flush()
            inbox.unlock()
            break          # Found destination, so stop looking.

for box in boxes.itervalues():
    box.close()
```

## 18.5 mllib — Access to MH mailboxes

Deprecated since version 2.6: The `mllib` module has been removed in Python 3. Use the `mailbox` instead. The `mllib` module provides a Python interface to MH folders and their contents.

The module contains three basic classes, `MH`, which represents a particular collection of folders, `Folder`, which represents a single folder, and `Message`, which represents a single message.

```
class mllib.MH([path[, profile]])
    MH represents a collection of MH folders.
```

```
class mllib.Folder(mh, name)
    The Folder class represents a single folder and its messages.
```

```
class mllib.Message(folder, number[, name])
    Message objects represent individual messages in a folder. The Message class is derived from mimertools.Message.
```

## 18.5.1 MH Objects

MH instances have the following methods:

- MH.**error** (*format*[, ... ])
  - Print an error message – can be overridden.
- MH.**getprofile** (*key*)
  - Return a profile entry (None if not set).
- MH.**getpath** ()
  - Return the mailbox pathname.
- MH.**getcontext** ()
  - Return the current folder name.
- MH.**setcontext** (*name*)
  - Set the current folder name.
- MH.**listfolders** ()
  - Return a list of top-level folders.
- MH.**listallfolders** ()
  - Return a list of all folders.
- MH.**listsubfolders** (*name*)
  - Return a list of direct subfolders of the given folder.
- MH.**listallsubfolders** (*name*)
  - Return a list of all subfolders of the given folder.
- MH.**makefolder** (*name*)
  - Create a new folder.
- MH.**deletefolder** (*name*)
  - Delete a folder – must have no subfolders.
- MH.**openfolder** (*name*)
  - Return a new open folder object.

## 18.5.2 Folder Objects

Folder instances represent open folders and have the following methods:

- Folder.**error** (*format*[, ... ])
  - Print an error message – can be overridden.
- Folder.**getfullname** ()
  - Return the folder's full pathname.
- Folder.**getsequencesfilename** ()
  - Return the full pathname of the folder's sequences file.
- Folder.**getmessagefilename** (*n*)
  - Return the full pathname of message *n* of the folder.
- Folder.**listmessages** ()
  - Return a list of messages in the folder (as numbers).
- Folder.**getcurrent** ()
  - Return the current message number.

`Folder.setcurrent` (*n*)

Set the current message number to *n*.

`Folder.parsesequence` (*seq*)

Parse msgs syntax into list of messages.

`Folder.getlast` ()

Get last message, or 0 if no messages are in the folder.

`Folder.setlast` (*n*)

Set last message (internal use only).

`Folder.getsequences` ()

Return dictionary of sequences in folder. The sequence names are used as keys, and the values are the lists of message numbers in the sequences.

`Folder.putsequences` (*dict*)

Return dictionary of sequences in folder name: list.

`Folder.removemessages` (*list*)

Remove messages in list from folder.

`Folder.refilemessages` (*list, tofolder*)

Move messages in list to other folder.

`Folder.movemessage` (*n, tofolder, ton*)

Move one message to a given destination in another folder.

`Folder.copymessage` (*n, tofolder, ton*)

Copy one message to a given destination in another folder.

### 18.5.3 Message Objects

The `Message` class adds one method to those of `mimertools.Message`:

`Message.openmessage` (*n*)

Return a new open message object (costs a file descriptor).

## 18.6 `mimertools` — Tools for parsing MIME messages

Deprecated since version 2.3: The `email` package should be used in preference to the `mimertools` module. This module is present only to maintain backward compatibility, and it has been removed in 3.x. This module defines a subclass of the `rfc822` module's `Message` class and a number of utility functions that are useful for the manipulation for MIME multipart or encoded message.

It defines the following items:

`class mimertools.Message` (*fp* [, *seekable* ])

Return a new instance of the `Message` class. This is a subclass of the `rfc822.Message` class, with some additional methods (see below). The *seekable* argument has the same meaning as for `rfc822.Message`.

`mimertools.choose_boundary` ()

Return a unique string that has a high likelihood of being usable as a part boundary. The string has the form 'hostipaddr.uid.pid.timestamp.random'.

`mimertools.decode` (*input, output, encoding*)

Read data encoded using the allowed MIME *encoding* from open file object *input* and write the decoded data to open file object *output*. Valid values for *encoding* include 'base64', 'quoted-printable',

'uuencode', 'x-uuencode', 'uue', 'x-uue', '7bit', and '8bit'. Decoding messages encoded in '7bit' or '8bit' has no effect. The input is simply copied to the output.

`mimertools.encode` (*input*, *output*, *encoding*)

Read data from open file object *input* and write it encoded using the allowed MIME *encoding* to open file object *output*. Valid values for *encoding* are the same as for `decode()`.

`mimertools.copyliteral` (*input*, *output*)

Read lines from open file *input* until EOF and write them to open file *output*.

`mimertools.copybinary` (*input*, *output*)

Read blocks until EOF from open file *input* and write them to open file *output*. The block size is currently fixed at 8192.

#### See Also:

**Module `email`** Comprehensive email handling package; supersedes the `mimertools` module.

**Module `rfc822`** Provides the base class for `mimertools.Message`.

**Module `multifile`** Support for reading files which contain distinct parts, such as MIME data.

<http://faqs.cs.uu.nl/na-dir/mail/mime-faq.html> The MIME Frequently Asked Questions document. For an overview of MIME, see the answer to question 1.1 in Part 1 of this document.

## 18.6.1 Additional Methods of Message Objects

The `Message` class defines the following methods in addition to the `rfc822.Message` methods:

`Message.getplist()`

Return the parameter list of the *Content-Type* header. This is a list of strings. For parameters of the form `key=value`, *key* is converted to lower case but *value* is not. For example, if the message contains the header `Content-type: text/html; spam=1; Spam=2; Spam` then `getplist()` will return the Python list `['spam=1', 'spam=2', 'Spam']`.

`Message.getparam(name)`

Return the *value* of the first parameter (as returned by `getplist()`) of the form `name=value` for the given *name*. If *value* is surrounded by quotes of the form `<...>` or `"..."`, these are removed.

`Message.getencoding()`

Return the encoding specified in the *Content-Transfer-Encoding* message header. If no such header exists, return `'7bit'`. The encoding is converted to lower case.

`Message.gettype()`

Return the message type (of the form `type/subtype`) as specified in the *Content-Type* header. If no such header exists, return `'text/plain'`. The type is converted to lower case.

`Message.getmaintype()`

Return the main type as specified in the *Content-Type* header. If no such header exists, return `'text'`. The main type is converted to lower case.

`Message.getsubtype()`

Return the subtype as specified in the *Content-Type* header. If no such header exists, return `'plain'`. The subtype is converted to lower case.

## 18.7 mimetypes — Map filenames to MIME types

Source code: <Lib/mimetypes.py>

The `mimetypes` module converts between a filename or URL and the MIME type associated with the filename extension. Conversions are provided from filename to MIME type and from MIME type to filename extension; encodings are not supported for the latter conversion.

The module provides one class and a number of convenience functions. The functions are the normal interface to this module, but some applications may be interested in the class as well.

The functions described below provide the primary interface for this module. If the module has not been initialized, they will call `init()` if they rely on the information `init()` sets up.

`mimetypes.guess_type(url, strict=True)`

Guess the type of a file based on its filename or URL, given by `url`. The return value is a tuple (`type`, `encoding`) where `type` is `None` if the type can't be guessed (missing or unknown suffix) or a string of the form `'type/subtype'`, usable for a MIME `content-type` header.

`encoding` is `None` for no encoding or the name of the program used to encode (e.g. `compress` or `gzip`). The encoding is suitable for use as a `Content-Encoding` header, **not** as a `Content-Transfer-Encoding` header. The mappings are table driven. Encoding suffixes are case sensitive; type suffixes are first tried case sensitively, then case insensitively.

The optional `strict` argument is a flag specifying whether the list of known MIME types is limited to only the official types registered with IANA. When `strict` is `True` (the default), only the IANA types are supported; when `strict` is `False`, some additional non-standard but commonly used MIME types are also recognized.

`mimetypes.guess_all_extensions(type, strict=True)`

Guess the extensions for a file based on its MIME type, given by `type`. The return value is a list of strings giving all possible filename extensions, including the leading dot (`'.'`). The extensions are not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type `type` by `guess_type()`.

The optional `strict` argument has the same meaning as with the `guess_type()` function.

`mimetypes.guess_extension(type, strict=True)`

Guess the extension for a file based on its MIME type, given by `type`. The return value is a string giving a filename extension, including the leading dot (`'.'`). The extension is not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type `type` by `guess_type()`. If no extension can be guessed for `type`, `None` is returned.

The optional `strict` argument has the same meaning as with the `guess_type()` function.

Some additional functions and data items are available for controlling the behavior of the module.

`mimetypes.init(files=None)`

Initialize the internal data structures. If given, `files` must be a sequence of file names which should be used to augment the default type map. If omitted, the file names to use are taken from `knownfiles`; on Windows, the current registry settings are loaded. Each file named in `files` or `knownfiles` takes precedence over those named before it. Calling `init()` repeatedly is allowed. Changed in version 2.7: Previously, Windows registry settings were ignored.

`mimetypes.read_mime_types(filename)`

Load the type map given in the file `filename`, if it exists. The type map is returned as a dictionary mapping filename extensions, including the leading dot (`'.'`), to strings of the form `'type/subtype'`. If the file `filename` does not exist or cannot be read, `None` is returned.

`mimetypes.add_type(type, ext, strict=True)`

Add a mapping from the MIME type `type` to the extension `ext`. When the extension is already known, the new type will replace the old one. When the type is already known the extension will be added to the list of known extensions.

When *strict* is `True` (the default), the mapping will be added to the official MIME types, otherwise to the non-standard ones.

#### `mimetypes.inited`

Flag indicating whether or not the global data structures have been initialized. This is set to `True` by `init()`.

#### `mimetypes.knownfiles`

List of type map file names commonly installed. These files are typically named `mime.types` and are installed in different locations by different packages.

#### `mimetypes.suffix_map`

Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately.

#### `mimetypes.encodings_map`

Dictionary mapping filename extensions to encoding types.

#### `mimetypes.types_map`

Dictionary mapping filename extensions to MIME types.

#### `mimetypes.common_types`

Dictionary mapping filename extensions to non-standard, but commonly found MIME types.

An example usage of the module:

```
>>> import mimetypes
>>> mimetypes.init()
>>> mimetypes.knownfiles
['/etc/mime.types', '/etc/httpd/mime.types', ... ]
>>> mimetypes.suffix_map['.tgz']
'.tar.gz'
>>> mimetypes.encodings_map['.gz']
'gzip'
>>> mimetypes.types_map['.tgz']
'application/x-tar-gz'
```

## 18.7.1 MimeTypes Objects

The `MimeTypes` class may be useful for applications which may want more than one MIME-type database; it provides an interface similar to the one of the `mimetypes` module.

**class** `mimetypes.MimeTypes` (*filenames=()*, *strict=True*)

This class represents a MIME-types database. By default, it provides access to the same database as the rest of this module. The initial database is a copy of that provided by the module, and may be extended by loading additional `mime.types`-style files into the database using the `read()` or `readfp()` methods. The mapping dictionaries may also be cleared before loading additional data if the default data is not desired.

The optional *filenames* parameter can be used to cause additional files to be loaded “on top” of the default database.

#### `MimeTypes.suffix_map`

Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately. This is initially a copy of the global `suffix_map` defined in the module.

### `MimeTypes.encodings_map`

Dictionary mapping filename extensions to encoding types. This is initially a copy of the global `encodings_map` defined in the module.

### `MimeTypes.types_map`

Tuple containing two dictionaries, mapping filename extensions to MIME types: the first dictionary is for the non-standards types and the second one is for the standard types. They are initialized by `common_types` and `types_map`.

### `MimeTypes.types_map_inv`

Tuple containing two dictionaries, mapping MIME types to a list of filename extensions: the first dictionary is for the non-standards types and the second one is for the standard types. They are initialized by `common_types` and `types_map`.

### `MimeTypes.guess_extension (type, strict=True)`

Similar to the `guess_extension()` function, using the tables stored as part of the object.

### `MimeTypes.guess_type (url, strict=True)`

Similar to the `guess_type()` function, using the tables stored as part of the object.

### `MimeTypes.guess_all_extensions (type, strict=True)`

Similar to the `guess_all_extensions()` function, using the tables stored as part of the object.

### `MimeTypes.read (filename, strict=True)`

Load MIME information from a file named *filename*. This uses `readfp()` to parse the file.

If *strict* is `True`, information will be added to list of standard types, else to the list of non-standard types.

### `MimeTypes.readfp (fp, strict=True)`

Load MIME type information from an open file *fp*. The file must have the format of the standard `mime.types` files.

If *strict* is `True`, information will be added to the list of standard types, else to the list of non-standard types.

### `MimeTypes.read_windows_registry (strict=True)`

Load MIME type information from the Windows registry. Availability: Windows.

If *strict* is `True`, information will be added to the list of standard types, else to the list of non-standard types. New in version 2.7.

## 18.8 MimeWriter — Generic MIME file writer

Deprecated since version 2.3: The `email` package should be used in preference to the `MimeWriter` module. This module is present only to maintain backward compatibility. This module defines the class `MimeWriter`. The `MimeWriter` class implements a basic formatter for creating MIME multi-part files. It doesn't seek around the output file nor does it use large amounts of buffer space. You must write the parts out in the order that they should occur in the final file. `MimeWriter` does buffer the headers you add, allowing you to rearrange their order.

### `class MimeWriter.MimeWriter (fp)`

Return a new instance of the `MimeWriter` class. The only argument passed, *fp*, is a file object to be used for writing. Note that a `StringIO` object could also be used.

### 18.8.1 MimeWriter Objects

`MimeWriter` instances have the following methods:

#### `MimeWriter.addheader (key, value[, prefix])`

Add a header line to the MIME message. The *key* is the name of the header, where the *value* obviously provides

the value of the header. The optional argument *prefix* determines where the header is inserted; 0 means append at the end, 1 is insert at the start. The default is to append.

`MimeWriter.flushheaders()`

Causes all headers accumulated so far to be written out (and forgotten). This is useful if you don't need a body part at all, e.g. for a subpart of type *message/rfc822* that's (mis)used to store some header-like information.

`MimeWriter.startbody(ctype[, plist[, prefix]])`

Returns a file-like object which can be used to write to the body of the message. The content-type is set to the provided *ctype*, and the optional parameter *plist* provides additional parameters for the content-type declaration. *prefix* functions as in `addheader()` except that the default is to insert at the start.

`MimeWriter.startmultipartbody(subtype[, boundary[, plist[, prefix]]])`

Returns a file-like object which can be used to write to the body of the message. Additionally, this method initializes the multi-part code, where *subtype* provides the multipart subtype, *boundary* may provide a user-defined boundary specification, and *plist* provides optional parameters for the subtype. *prefix* functions as in `startbody()`. Subparts should be created using `nextpart()`.

`MimeWriter.nextpart()`

Returns a new instance of `MimeWriter` which represents an individual part in a multipart message. This may be used to write the part as well as used for creating recursively complex multipart messages. The message must first be initialized with `startmultipartbody()` before using `nextpart()`.

`MimeWriter.lastpart()`

This is used to designate the last part of a multipart message, and should *always* be used when writing multipart messages.

## 18.9 `mimify` — MIME processing of mail messages

Deprecated since version 2.3: The `email` package should be used in preference to the `mimify` module. This module is present only to maintain backward compatibility. The `mimify` module defines two functions to convert mail messages to and from MIME format. The mail message can be either a simple message or a so-called multipart message. Each part is treated separately. Mimifying (a part of) a message entails encoding the message as quoted-printable if it contains any characters that cannot be represented using 7-bit ASCII. Unmimifying (a part of) a message entails undoing the quoted-printable encoding. Mimify and unmimify are especially useful when a message has to be edited before being sent. Typical use would be:

```
unmimify message
edit message
mimify message
send message
```

The modules defines the following user-callable functions and user-settable variables:

`mimify.mimify(infile, outfile)`

Copy the message in *infile* to *outfile*, converting parts to quoted-printable and adding MIME mail headers when necessary. *infile* and *outfile* can be file objects (actually, any object that has a `readline()` method (for *infile*) or a `write()` method (for *outfile*)) or strings naming the files. If *infile* and *outfile* are both strings, they may have the same value.

`mimify.unmimify(infile, outfile[, decode_base64])`

Copy the message in *infile* to *outfile*, decoding all quoted-printable parts. *infile* and *outfile* can be file objects (actually, any object that has a `readline()` method (for *infile*) or a `write()` method (for *outfile*)) or strings naming the files. If *infile* and *outfile* are both strings, they may have the same value. If the *decode\_base64* argument is provided and tests true, any parts that are coded in the base64 encoding are decoded as well.

`mimify.mime_decode_header` (*line*)

Return a decoded version of the encoded header line in *line*. This only supports the ISO 8859-1 charset (Latin-1).

`mimify.mime_encode_header` (*line*)

Return a MIME-encoded version of the header line in *line*.

`mimify.MAXLEN`

By default, a part will be encoded as quoted-printable when it contains any non-ASCII characters (characters with the 8th bit set), or if there are any lines longer than `MAXLEN` characters (default value 200).

`mimify.CHARSET`

When not specified in the mail headers, a character set must be filled in. The string used is stored in `CHARSET`, and the default value is ISO-8859-1 (also known as Latin1 (latin-one)).

This module can also be used from the command line. Usage is as follows:

```
mimify.py -e [-l length] [infile [outfile]]
mimify.py -d [-b] [infile [outfile]]
```

to encode (`mimify`) and decode (`unmimify`) respectively. *infile* defaults to standard input, *outfile* defaults to standard output. The same file can be specified for input and output.

If the `-l` option is given when encoding, if there are any lines longer than the specified *length*, the containing part will be encoded.

If the `-b` option is given when decoding, any base64 parts will be decoded as well.

**See Also:**

**Module `quopri`** Encode and decode MIME quoted-printable files.

## 18.10 `multifile` — Support for files containing distinct parts

Deprecated since version 2.5: The `email` package should be used in preference to the `multifile` module. This module is present only to maintain backward compatibility. The `MultiFile` object enables you to treat sections of a text file as file-like input objects, with `"` being returned by `readline()` when a given delimiter pattern is encountered. The defaults of this class are designed to make it useful for parsing MIME multipart messages, but by subclassing it and overriding methods it can be easily adapted for more general use.

**class** `multifile.MultiFile` (*fp*[, *seekable*])

Create a multi-file. You must instantiate this class with an input object argument for the `MultiFile` instance to get lines from, such as a file object returned by `open()`.

`MultiFile` only ever looks at the input object's `readline()`, `seek()` and `tell()` methods, and the latter two are only needed if you want random access to the individual MIME parts. To use `MultiFile` on a non-seekable stream object, set the optional *seekable* argument to false; this will prevent using the input object's `seek()` and `tell()` methods.

It will be useful to know that in `MultiFile`'s view of the world, text is composed of three kinds of lines: data, section-dividers, and end-markers. `MultiFile` is designed to support parsing of messages that may have multiple nested message parts, each with its own pattern for section-divider and end-marker lines.

**See Also:**

**Module `email`** Comprehensive email handling package; supersedes the `multifile` module.

### 18.10.1 `MultiFile` Objects

A `MultiFile` instance has the following methods:

`MultiFile.readline(str)`

Read a line. If the line is data (not a section-divider or end-marker or real EOF) return it. If the line matches the most-recently-stacked boundary, return "" and set `self.last` to 1 or 0 according as the match is or is not an end-marker. If the line matches any other stacked boundary, raise an error. On encountering end-of-file on the underlying stream object, the method raises `ERROR` unless all boundaries have been popped.

`MultiFile.readlines(str)`

Return all lines remaining in this part as a list of strings.

`MultiFile.read()`

Read all lines, up to the next section. Return them as a single (multiline) string. Note that this doesn't take a size argument!

`MultiFile.seek(pos[, whence])`

Seek. Seek indices are relative to the start of the current section. The *pos* and *whence* arguments are interpreted as for a file seek.

`MultiFile.tell()`

Return the file position relative to the start of the current section.

`MultiFile.next()`

Skip lines to the next section (that is, read lines until a section-divider or end-marker has been consumed). Return true if there is such a section, false if an end-marker is seen. Re-enable the most-recently-pushed boundary.

`MultiFile.is_data(str)`

Return true if *str* is data and false if it might be a section boundary. As written, it tests for a prefix other than '--' at start of line (which all MIME boundaries have) but it is declared so it can be overridden in derived classes.

Note that this test is used intended as a fast guard for the real boundary tests; if it always returns false it will merely slow processing, not cause it to fail.

`MultiFile.push(str)`

Push a boundary string. When a decorated version of this boundary is found as an input line, it will be interpreted as a section-divider or end-marker (depending on the decoration, see [RFC 2045](#)). All subsequent reads will return the empty string to indicate end-of-file, until a call to `pop()` removes the boundary or `next()` call reenables it.

It is possible to push more than one boundary. Encountering the most-recently-pushed boundary will return EOF; encountering any other boundary will raise an error.

`MultiFile.pop()`

Pop a section boundary. This boundary will no longer be interpreted as EOF.

`MultiFile.section_divider(str)`

Turn a boundary into a section-divider line. By default, this method prepends '--' (which MIME section boundaries have) but it is declared so it can be overridden in derived classes. This method need not append LF or CR-LF, as comparison with the result ignores trailing whitespace.

`MultiFile.end_marker(str)`

Turn a boundary string into an end-marker line. By default, this method prepends '--' and appends '--' (like a MIME-multipart end-of-message marker) but it is declared so it can be overridden in derived classes. This method need not append LF or CR-LF, as comparison with the result ignores trailing whitespace.

Finally, `MultiFile` instances have two public instance variables:

`MultiFile.level`

Nesting depth of the current part.

`MultiFile.last`

True if the last end-of-file was for an end-of-message marker.

## 18.10.2 MultiFile Example

```
import mimetools
import multifile
import StringIO

def extract_mime_part_matching(stream, mimetype):
    """Return the first element in a multipart MIME message on stream
    matching mimetype."""

    msg = mimetools.Message(stream)
    msgtype = msg.gettype()
    params = msg.getplist()

    data = StringIO.StringIO()
    if msgtype[:10] == "multipart/":

        file = multifile.MultiFile(stream)
        file.push(msg.getparam("boundary"))
        while file.next():
            submsg = mimetools.Message(file)
            try:
                data = StringIO.StringIO()
                mimetools.decode(file, data, submsg.getencoding())
            except ValueError:
                continue
            if submsg.gettype() == mimetype:
                break
        file.pop()
    return data.getvalue()
```

## 18.11 rfc822 — Parse RFC 2822 mail headers

Deprecated since version 2.3: The `email` package should be used in preference to the `rfc822` module. This module is present only to maintain backward compatibility, and has been removed in Python 3. This module defines a class, `Message`, which represents an “email message” as defined by the Internet standard [RFC 2822](#).<sup>8</sup> Such messages consist of a collection of message headers, and a message body. This module also defines a helper class `AddressList` for parsing [RFC 2822](#) addresses. Please refer to the RFC for information on the specific syntax of

[RFC 2822](#) messages.

The `mailbox` module provides classes to read mailboxes produced by various end-user mail programs.

**class** `rfc822.Message` (*file* [, *seekable* ])

A `Message` instance is instantiated with an input object as parameter. `Message` relies only on the input object having a `readline()` method; in particular, ordinary file objects qualify. Instantiation reads headers from the input object up to a delimiter line (normally a blank line) and stores them in the instance. The message body, following the headers, is not consumed.

This class can work with any input object that supports a `readline()` method. If the input object has `seek` and `tell` capability, the `rewindbody()` method will work; also, illegal lines will be pushed back onto the

---

<sup>8</sup> This module originally conformed to [RFC 822](#), hence the name. Since then, [RFC 2822](#) has been released as an update to [RFC 822](#). This module should be considered [RFC 2822](#)-conformant, especially in cases where the syntax or semantics have changed since [RFC 822](#).

input stream. If the input object lacks `seek` but has an `unread()` method that can push back a line of input, `Message` will use that to push back illegal lines. Thus this class can be used to parse messages coming from a buffered stream.

The optional `seekable` argument is provided as a workaround for certain stdio libraries in which `tell()` discards buffered data before discovering that the `lseek()` system call doesn't work. For maximum portability, you should set the `seekable` argument to zero to prevent that initial `tell()` when passing in an unseekable object such as a file object created from a socket object.

Input lines as read from the file may either be terminated by CR-LF or by a single linefeed; a terminating CR-LF is replaced by a single linefeed before the line is stored.

All header matching is done independent of upper or lower case; e.g. `m['From']`, `m['from']` and `m['FROM']` all yield the same result.

**class** `rfc822.AddressList` (*field*)

You may instantiate the `AddressList` helper class using a single string parameter, a comma-separated list of **RFC 2822** addresses to be parsed. (The parameter `None` yields an empty list.)

`rfc822.quote` (*str*)

Return a new string with backslashes in *str* replaced by two backslashes and double quotes replaced by backslash-double quote.

`rfc822.unquote` (*str*)

Return a new string which is an *unquoted* version of *str*. If *str* ends and begins with double quotes, they are stripped off. Likewise if *str* ends and begins with angle brackets, they are stripped off.

`rfc822.parseaddr` (*address*)

Parse *address*, which should be the value of some address-containing field such as *To* or *Cc*, into its constituent “realname” and “email address” parts. Returns a tuple of that information, unless the parse fails, in which case a 2-tuple (`None`, `None`) is returned.

`rfc822.dump_address_pair` (*pair*)

The inverse of `parseaddr()`, this takes a 2-tuple of the form (*realname*, *email\_address*) and returns the string value suitable for a *To* or *Cc* header. If the first element of *pair* is false, then the second element is returned unmodified.

`rfc822.parsedate` (*date*)

Attempts to parse a date according to the rules in **RFC 2822**. however, some mailers don't follow that format as specified, so `parsedate()` tries to guess correctly in such cases. *date* is a string containing an **RFC 2822** date, such as `'Mon, 20 Nov 1995 19:12:08 -0500'`. If it succeeds in parsing the date, `parsedate()` returns a 9-tuple that can be passed directly to `time.mktime()`; otherwise `None` will be returned. Note that indexes 6, 7, and 8 of the result tuple are not usable.

`rfc822.parsedate_tz` (*date*)

Performs the same function as `parsedate()`, but returns either `None` or a 10-tuple; the first 9 elements make up a tuple that can be passed directly to `time.mktime()`, and the tenth is the offset of the date's timezone from UTC (which is the official term for Greenwich Mean Time). (Note that the sign of the timezone offset is the opposite of the sign of the `time.timezone` variable for the same timezone; the latter variable follows the POSIX standard while this module follows **RFC 2822**.) If the input string has no timezone, the last element of the tuple returned is `None`. Note that indexes 6, 7, and 8 of the result tuple are not usable.

`rfc822.mktime_tz` (*tuple*)

Turn a 10-tuple as returned by `parsedate_tz()` into a UTC timestamp. If the timezone item in the tuple is `None`, assume local time. Minor deficiency: this first interprets the first 8 elements as a local time and then compensates for the timezone difference; this may yield a slight error around daylight savings time switch dates. Not enough to worry about for common use.

**See Also:**

**Module `email`** Comprehensive email handling package; supersedes the `rfc822` module.

**Module `mailbox`** Classes to read various mailbox formats produced by end-user mail programs.

**Module `mimertools`** Subclass of `rfc822.Message` that handles MIME encoded messages.

### 18.11.1 Message Objects

A `Message` instance has the following methods:

`Message.rewindbody()`

Seek to the start of the message body. This only works if the file object is seekable.

`Message.isheader(line)`

Returns a line's canonicalized fieldname (the dictionary key that will be used to index it) if the line is a legal **RFC 2822** header; otherwise returns `None` (implying that parsing should stop here and the line be pushed back on the input stream). It is sometimes useful to override this method in a subclass.

`Message.islast(line)`

Return true if the given line is a delimiter on which `Message` should stop. The delimiter line is consumed, and the file object's read location positioned immediately after it. By default this method just checks that the line is blank, but you can override it in a subclass.

`Message.iscomment(line)`

Return `True` if the given line should be ignored entirely, just skipped. By default this is a stub that always returns `False`, but you can override it in a subclass.

`Message.getallmatchingheaders(name)`

Return a list of lines consisting of all headers matching *name*, if any. Each physical line, whether it is a continuation line or not, is a separate list item. Return the empty list if no header matches *name*.

`Message.getfirstmatchingheader(name)`

Return a list of lines comprising the first header matching *name*, and its continuation line(s), if any. Return `None` if there is no header matching *name*.

`Message.getrawheader(name)`

Return a single string consisting of the text after the colon in the first header matching *name*. This includes leading whitespace, the trailing linefeed, and internal linefeeds and whitespace if there any continuation line(s) were present. Return `None` if there is no header matching *name*.

`Message.getheader(name[, default])`

Return a single string consisting of the last header matching *name*, but strip leading and trailing whitespace. Internal whitespace is not stripped. The optional *default* argument can be used to specify a different default to be returned when there is no header matching *name*; it defaults to `None`. This is the preferred way to get parsed headers.

`Message.get(name[, default])`

An alias for `getheader()`, to make the interface more compatible with regular dictionaries.

`Message.getaddr(name)`

Return a pair (full name, email address) parsed from the string returned by `getheader(name)`. If no header matching *name* exists, return `(None, None)`; otherwise both the full name and the address are (possibly empty) strings.

Example: If *m*'s first *From* header contains the string `'jack@cwi.nl (Jack Jansen)'`, then `m.getaddr('From')` will yield the pair `('Jack Jansen', 'jack@cwi.nl')`. If the header contained `'Jack Jansen <jack@cwi.nl>'` instead, it would yield the exact same result.

`Message.getaddrlist(name)`

This is similar to `getaddr(list)`, but parses a header containing a list of email addresses (e.g. a *To* header)

and returns a list of (full name, email address) pairs (even if there was only one address in the header). If there is no header matching *name*, return an empty list.

If multiple headers exist that match the named header (e.g. if there are several *Cc* headers), all are parsed for addresses. Any continuation lines the named headers contain are also parsed.

`Message.getdate(name)`

Retrieve a header using `getheader()` and parse it into a 9-tuple compatible with `time.mktime()`; note that fields 6, 7, and 8 are not usable. If there is no header matching *name*, or it is unparseable, return `None`.

Date parsing appears to be a black art, and not all mailers adhere to the standard. While it has been tested and found correct on a large collection of email from many sources, it is still possible that this function may occasionally yield an incorrect result.

`Message.getdate_tz(name)`

Retrieve a header using `getheader()` and parse it into a 10-tuple; the first 9 elements will make a tuple compatible with `time.mktime()`, and the 10th is a number giving the offset of the date's timezone from UTC. Note that fields 6, 7, and 8 are not usable. Similarly to `getdate()`, if there is no header matching *name*, or it is unparseable, return `None`.

`Message` instances also support a limited mapping interface. In particular: `m[name]` is like `m.getheader(name)` but raises `KeyError` if there is no matching header; and `len(m)`, `m.get(name[, default])`, `name in m`, `m.keys()`, `m.values()`, `m.items()`, and `m.setdefault(name[, default])` act as expected, with the one difference that `setdefault()` uses an empty string as the default value. `Message` instances also support the mapping writable interface `m[name] = value` and `del m[name]`. `Message` objects do not support the `clear()`, `copy()`, `popitem()`, or `update()` methods of the mapping interface. (Support for `get()` and `setdefault()` was only added in Python 2.2.)

Finally, `Message` instances have some public instance variables:

`Message.headers`

A list containing the entire set of header lines, in the order in which they were read (except that `setitem` calls may disturb this order). Each line contains a trailing newline. The blank line terminating the headers is not contained in the list.

`Message.fp`

The file or file-like object passed at instantiation time. This can be used to read the message content.

`Message.unixfrom`

The Unix `From` line, if the message had one, or an empty string. This is needed to regenerate the message in some contexts, such as an `mbox`-style mailbox file.

## 18.11.2 AddressList Objects

An `AddressList` instance has the following methods:

`AddressList.__len__()`

Return the number of addresses in the address list.

`AddressList.__str__()`

Return a canonicalized string representation of the address list. Addresses are rendered in “name” `<host@domain>` form, comma-separated.

`AddressList.__add__(alist)`

Return a new `AddressList` instance that contains all addresses in both `AddressList` operands, with duplicates removed (set union).

`AddressList.__iadd__(alist)`

In-place version of `__add__()`; turns this `AddressList` instance into the union of itself and the right-hand instance, *alist*.

`AddressList.__sub__` (*alist*)

Return a new `AddressList` instance that contains every address in the left-hand `AddressList` operand that is not present in the right-hand address operand (set difference).

`AddressList.__isub__` (*alist*)

In-place version of `__sub__()`, removing addresses in this list which are also in *alist*.

Finally, `AddressList` instances have one public instance variable:

`AddressList.addresslist`

A list of tuple string pairs, one per address. In each member, the first is the canonicalized name part, the second is the actual route-address ('@'-separated username-host.domain pair).

## 18.12 base64 — RFC 3548: Base16, Base32, Base64 Data Encodings

This module provides data encoding and decoding as specified in [RFC 3548](#). This standard defines the Base16, Base32, and Base64 algorithms for encoding and decoding arbitrary binary strings into text strings that can be safely sent by email, used as parts of URLs, or included as part of an HTTP POST request. The encoding algorithm is not the same as the `uuencode` program.

There are two interfaces provided by this module. The modern interface supports encoding and decoding string objects using all three alphabets. The legacy interface provides for encoding and decoding to and from file-like objects as well as strings, but only using the Base64 standard alphabet.

The modern interface, which was introduced in Python 2.4, provides:

`base64.b64encode` (*s* [, *altchars* ])

Encode a string use Base64.

*s* is the string to encode. Optional *altchars* must be a string of at least length 2 (additional characters are ignored) which specifies an alternative alphabet for the + and / characters. This allows an application to e.g. generate URL or filesystem safe Base64 strings. The default is `None`, for which the standard Base64 alphabet is used.

The encoded string is returned.

`base64.b64decode` (*s* [, *altchars* ])

Decode a Base64 encoded string.

*s* is the string to decode. Optional *altchars* must be a string of at least length 2 (additional characters are ignored) which specifies the alternative alphabet used instead of the + and / characters.

The decoded string is returned. A `TypeError` is raised if *s* were incorrectly padded or if there are non-alphabet characters present in the string.

`base64.standard_b64encode` (*s*)

Encode string *s* using the standard Base64 alphabet.

`base64.standard_b64decode` (*s*)

Decode string *s* using the standard Base64 alphabet.

`base64.urlsafe_b64encode` (*s*)

Encode string *s* using a URL-safe alphabet, which substitutes - instead of + and \_ instead of / in the standard Base64 alphabet. The result can still contain =.

`base64.urlsafe_b64decode` (*s*)

Decode string *s* using a URL-safe alphabet, which substitutes - instead of + and \_ instead of / in the standard Base64 alphabet.

`base64.b32encode` (*s*)

Encode a string using Base32. *s* is the string to encode. The encoded string is returned.

`base64.b32decode(s[, casefold[, map01]])`  
 Decode a Base32 encoded string.

*s* is the string to decode. Optional *casefold* is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is `False`.

**RFC 3548** allows for optional mapping of the digit 0 (zero) to the letter O (oh), and for optional mapping of the digit 1 (one) to either the letter I (eye) or letter L (el). The optional argument *map01* when not `None`, specifies which letter the digit 1 should be mapped to (when *map01* is not `None`, the digit 0 is always mapped to the letter O). For security purposes the default is `None`, so that 0 and 1 are not allowed in the input.

The decoded string is returned. A `TypeError` is raised if *s* were incorrectly padded or if there are non-alphabet characters present in the string.

`base64.b16encode(s)`  
 Encode a string using Base16.

*s* is the string to encode. The encoded string is returned.

`base64.b16decode(s[, casefold])`  
 Decode a Base16 encoded string.

*s* is the string to decode. Optional *casefold* is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is `False`.

The decoded string is returned. A `TypeError` is raised if *s* were incorrectly padded or if there are non-alphabet characters present in the string.

The legacy interface:

`base64.decode(input, output)`

Decode the contents of the *input* file and write the resulting binary data to the *output* file. *input* and *output* must either be file objects or objects that mimic the file object interface. *input* will be read until `input.read()` returns an empty string.

`base64.decodestring(s)`

Decode the string *s*, which must contain one or more lines of base64 encoded data, and return a string containing the resulting binary data.

`base64.encode(input, output)`

Encode the contents of the *input* file and write the resulting base64 encoded data to the *output* file. *input* and *output* must either be file objects or objects that mimic the file object interface. *input* will be read until `input.read()` returns an empty string. `encode()` returns the encoded data plus a trailing newline character (`'\n'`).

`base64.encodestring(s)`

Encode the string *s*, which can contain arbitrary binary data, and return a string containing one or more lines of base64-encoded data. `encodestring()` returns a string containing one or more lines of base64-encoded data always including an extra trailing newline (`'\n'`).

An example usage of the module:

```
>>> import base64
>>> encoded = base64.b64encode('data to be encoded')
>>> encoded
'ZGF0YSB0byBiZSB1bmlmNvZGVk'
>>> data = base64.b64decode(encoded)
>>> data
'data to be encoded'
```

**See Also:**

**Module `binascii`** Support module containing ASCII-to-binary and binary-to-ASCII conversions.

**RFC 1521 - MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Describing the Format**  
Section 5.2, “Base64 Content-Transfer-Encoding,” provides the definition of the base64 encoding.

## 18.13 `binhex` — Encode and decode binhex4 files

This module encodes and decodes files in binhex4 format, a format allowing representation of Macintosh files in ASCII. On the Macintosh, both forks of a file and the finder information are encoded (or decoded), on other platforms only the data fork is handled.

---

**Note:** In Python 3.x, special Macintosh support has been removed.

---

The `binhex` module defines the following functions:

`binhex.binhex` (*input*, *output*)

Convert a binary file with filename *input* to binhex file *output*. The *output* parameter can either be a filename or a file-like object (any object supporting a `write()` and `close()` method).

`binhex.hexbin` (*input*[, *output* ])

Decode a binhex file *input*. *input* may be a filename or a file-like object supporting `read()` and `close()` methods. The resulting file is written to a file named *output*, unless the argument is omitted in which case the output filename is read from the binhex file.

The following exception is also defined:

**exception `binhex.Error`**

Exception raised when something can't be encoded using the binhex format (for example, a filename is too long to fit in the filename field), or when input is not properly encoded binhex data.

**See Also:**

**Module `binascii`** Support module containing ASCII-to-binary and binary-to-ASCII conversions.

### 18.13.1 Notes

There is an alternative, more powerful interface to the coder and decoder, see the source for details.

If you code or decode textfiles on non-Macintosh platforms they will still use the old Macintosh newline convention (carriage-return as end of line).

As of this writing, `hexbin()` appears to not work in all cases.

## 18.14 `binascii` — Convert between binary and ASCII

The `binascii` module contains a number of methods to convert between binary and various ASCII-encoded binary representations. Normally, you will not use these functions directly but use wrapper modules like `uu`, `base64`, or `binhex` instead. The `binascii` module contains low-level functions written in C for greater speed that are used by the higher-level modules.

The `binascii` module defines the following functions:

`binascii.a2b_uu` (*string*)

Convert a single line of uuencoded data back to binary and return the binary data. Lines normally contain 45 (binary) bytes, except for the last line. Line data may be followed by whitespace.

`binascii.b2a_uu` (*data*)

Convert binary data to a line of ASCII characters, the return value is the converted line, including a newline char. The length of *data* should be at most 45.

`binascii.a2b_base64` (*string*)

Convert a block of base64 data back to binary and return the binary data. More than one line may be passed at a time.

`binascii.b2a_base64` (*data*)

Convert binary data to a line of ASCII characters in base64 coding. The return value is the converted line, including a newline char. The length of *data* should be at most 57 to adhere to the base64 standard.

`binascii.a2b_qp` (*string*[, *header*])

Convert a block of quoted-printable data back to binary and return the binary data. More than one line may be passed at a time. If the optional argument *header* is present and true, underscores will be decoded as spaces.

`binascii.b2a_qp` (*data*[, *quotetabs*, *istext*, *header*])

Convert binary data to a line(s) of ASCII characters in quoted-printable encoding. The return value is the converted line(s). If the optional argument *quotetabs* is present and true, all tabs and spaces will be encoded. If the optional argument *istext* is present and true, newlines are not encoded but trailing whitespace will be encoded. If the optional argument *header* is present and true, spaces will be encoded as underscores per RFC1522. If the optional argument *header* is present and false, newline characters will be encoded as well; otherwise linefeed conversion might corrupt the binary data stream.

`binascii.a2b_hqx` (*string*)

Convert binhex4 formatted ASCII data to binary, without doing RLE-decompression. The string should contain a complete number of binary bytes, or (in case of the last portion of the binhex4 data) have the remaining bits zero.

`binascii.rledecode_hqx` (*data*)

Perform RLE-decompression on the data, as per the binhex4 standard. The algorithm uses 0x90 after a byte as a repeat indicator, followed by a count. A count of 0 specifies a byte value of 0x90. The routine returns the decompressed data, unless data input data ends in an orphaned repeat indicator, in which case the `Incomplete` exception is raised.

`binascii.rlecode_hqx` (*data*)

Perform binhex4 style RLE-compression on *data* and return the result.

`binascii.b2a_hqx` (*data*)

Perform hexbin4 binary-to-ASCII translation and return the resulting string. The argument should already be RLE-coded, and have a length divisible by 3 (except possibly the last fragment).

`binascii.crc_hqx` (*data*, *crc*)

Compute the binhex4 crc value of *data*, starting with an initial *crc* and returning the result.

`binascii.crc32` (*data*[, *crc*])

Compute CRC-32, the 32-bit checksum of data, starting with an initial *crc*. This is consistent with the ZIP file checksum. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm. Use as follows:

```
print binascii.crc32("hello world")
# Or, in two pieces:
crc = binascii.crc32("hello")
crc = binascii.crc32(" world", crc) & 0xffffffff
print 'crc32 = 0x%08x' % crc
```

**Note:** To generate the same numeric value across all Python versions and platforms use `crc32(data) & 0xffffffff`. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32bit

binary representation regardless of sign.

---

Changed in version 2.6: The return value is in the range  $[-2^{31}, 2^{31}-1]$  regardless of platform. In the past the value would be signed on some platforms and unsigned on others. Use `& 0xffffffff` on the value if you want it to match Python 3 behavior. Changed in version 3.0: The return value is unsigned and in the range  $[0, 2^{32}-1]$  regardless of platform.

`binascii.b2a_hex(data)`

`binascii.hexlify(data)`

Return the hexadecimal representation of the binary *data*. Every byte of *data* is converted into the corresponding 2-digit hex representation. The resulting string is therefore twice as long as the length of *data*.

`binascii.a2b_hex(hexstr)`

`binascii.unhexlify(hexstr)`

Return the binary data represented by the hexadecimal string *hexstr*. This function is the inverse of `b2a_hex()`. *hexstr* must contain an even number of hexadecimal digits (which can be upper or lower case), otherwise a `TypeError` is raised.

**exception** `binascii.Error`

Exception raised on errors. These are usually programming errors.

**exception** `binascii.Incomplete`

Exception raised on incomplete data. These are usually not programming errors, but may be handled by reading a little more data and trying again.

**See Also:**

**Module** `base64` Support for base64 encoding used in MIME email messages.

**Module** `binhex` Support for the binhex format used on the Macintosh.

**Module** `uu` Support for UU encoding used on Unix.

**Module** `quopri` Support for quoted-printable encoding used in MIME email messages.

## 18.15 quopri — Encode and decode MIME quoted-printable data

**Source code:** [Lib/quopri.py](#)

---

This module performs quoted-printable transport encoding and decoding, as defined in [RFC 1521](#): “MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Describing the Format of Internet Message Bodies”. The quoted-printable encoding is designed for data where there are relatively few nonprintable characters; the base64 encoding scheme available via the `base64` module is more compact if there are many such characters, as when sending a graphics file.

`quopri.decode(input, output[, header])`

Decode the contents of the *input* file and write the resulting decoded binary data to the *output* file. *input* and *output* must either be file objects or objects that mimic the file object interface. *input* will be read until `input.readline()` returns an empty string. If the optional argument *header* is present and true, underscore will be decoded as space. This is used to decode “Q”-encoded headers as described in [RFC 1522](#): “MIME (Multipurpose Internet Mail Extensions) Part Two: Message Header Extensions for Non-ASCII Text”.

`quopri.encode(input, output, quotetabs)`

Encode the contents of the *input* file and write the resulting quoted-printable data to the *output* file. *input* and *output* must either be file objects or objects that mimic the file object interface. *input* will be read until `input.readline()` returns an empty string. *quotetabs* is a flag which controls whether to encode embedded

spaces and tabs; when true it encodes such embedded whitespace, and when false it leaves them unencoded. Note that spaces and tabs appearing at the end of lines are always encoded, as per [RFC 1521](#).

`quopri.decodestring(s[, header])`

Like `decode()`, except that it accepts a source string and returns the corresponding decoded string.

`quopri.encodestring(s[, quotetabs])`

Like `encode()`, except that it accepts a source string and returns the corresponding encoded string. `quotetabs` is optional (defaulting to 0), and is passed straight through to `encode()`.

**See Also:**

**Module `mimify`** General utilities for processing of MIME messages.

**Module `base64`** Encode and decode MIME base64 data

## 18.16 uu — Encode and decode uuencode files

**Source code:** [Lib/uu.py](#)

This module encodes and decodes files in uuencode format, allowing arbitrary binary data to be transferred over ASCII-only connections. Wherever a file argument is expected, the methods accept a file-like object. For backwards compatibility, a string containing a pathname is also accepted, and the corresponding file will be opened for reading and writing; the pathname `'-'` is understood to mean the standard input or output. However, this interface is deprecated; it's better for the caller to open the file itself, and be sure that, when required, the mode is `'rb'` or `'wb'` on Windows.

This code was contributed by Lance Ellinghouse, and modified by Jack Jansen.

The `uu` module defines the following functions:

`uu.encode(in_file, out_file[, name[, mode]])`

Uuencode file `in_file` into file `out_file`. The uuencoded file will have the header specifying `name` and `mode` as the defaults for the results of decoding the file. The default defaults are taken from `in_file`, or `'-'` and `0666` respectively.

`uu.decode(in_file[, out_file[, mode[, quiet]]])`

This call decodes uuencoded file `in_file` placing the result on file `out_file`. If `out_file` is a pathname, `mode` is used to set the permission bits if the file must be created. Defaults for `out_file` and `mode` are taken from the uuencode header. However, if the file specified in the header already exists, a `uu.Error` is raised.

`decode()` may print a warning to standard error if the input was produced by an incorrect uuencoder and Python could recover from that error. Setting `quiet` to a true value silences this warning.

**exception `uu.Error`**

Subclass of `Exception`, this can be raised by `uu.decode()` under various situations, such as described above, but also including a badly formatted header, or truncated input file.

**See Also:**

**Module `binascii`** Support module containing ASCII-to-binary and binary-to-ASCII conversions.



# STRUCTURED MARKUP PROCESSING TOOLS

Python supports a variety of modules to work with various forms of structured data markup. This includes modules to work with the Standard Generalized Markup Language (SGML) and the Hypertext Markup Language (HTML), and several interfaces for working with the Extensible Markup Language (XML).

It is important to note that modules in the `xml` package require that there be at least one SAX-compliant XML parser available. Starting with Python 2.3, the Expat parser is included with Python, so the `xml.parsers.expat` module will always be available. You may still want to be aware of the [PyXML add-on package](#); that package provides an extended set of XML libraries for Python.

The documentation for the `xml.dom` and `xml.sax` packages are the definition of the Python bindings for the DOM and SAX interfaces.

## 19.1 HTMLParser — Simple HTML and XHTML parser

---

**Note:** The `HTMLParser` module has been renamed to `html.parser` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

New in version 2.2. **Source code:** [Lib/HTMLParser.py](#)

---

This module defines a class `HTMLParser` which serves as the basis for parsing text files formatted in HTML (Hypertext Mark-up Language) and XHTML. Unlike the parser in `htmllib`, this parser is not based on the SGML parser in `sgmlib`.

### class `HTMLParser.HTMLParser`

An `HTMLParser` instance is fed HTML data and calls handler methods when start tags, end tags, text, comments, and other markup elements are encountered. The user should subclass `HTMLParser` and override its methods to implement the desired behavior.

The `HTMLParser` class is instantiated without arguments.

Unlike the parser in `htmllib`, this parser does not check that end tags match start tags or call the end-tag handler for elements which are closed implicitly by closing an outer element.

An exception is defined as well:

**exception** `HTMLParser.HTMLParseError`

`HTMLParser` is able to handle broken markup, but in some cases it might raise this exception when it encounters an error while parsing. This exception provides three attributes: `msg` is a brief message explaining the error, `lineno` is the number of the line on which the broken construct was detected, and `offset` is the number of characters into the line at which the construct starts.

### 19.1.1 Example HTML Parser Application

As a basic example, below is a simple HTML parser that uses the `HTMLParser` class to print out start tags, end tags and data as they are encountered:

```
from HTMLParser import HTMLParser

# create a subclass and override the handler methods
class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print "Encountered a start tag:", tag
    def handle_endtag(self, tag):
        print "Encountered an end tag :", tag
    def handle_data(self, data):
        print "Encountered some data :", data

# instantiate the parser and fed it some HTML
parser = MyHTMLParser()
parser.feed('<html><head><title>Test</title></head>'
          '<body><h1>Parse me!</h1></body></html>')
```

The output will then be:

```
Encountered a start tag: html
Encountered a start tag: head
Encountered a start tag: title
Encountered some data : Test
Encountered an end tag : title
Encountered an end tag : head
Encountered a start tag: body
Encountered a start tag: h1
Encountered some data : Parse me!
Encountered an end tag : h1
Encountered an end tag : body
Encountered an end tag : html
```

### 19.1.2 HTMLParser Methods

`HTMLParser` instances have the following methods:

`HTMLParser.feed(data)`

Feed some text to the parser. It is processed insofar as it consists of complete elements; incomplete data is buffered until more data is fed or `close()` is called. `data` can be either `unicode` or `str`, but passing `unicode` is advised.

`HTMLParser.close()`

Force processing of all buffered data as if it were followed by an end-of-file mark. This method may be redefined by a derived class to define additional processing at the end of the input, but the redefined version should always call the `HTMLParser` base class method `close()`.

`HTMLParser.reset()`

Reset the instance. Loses all unprocessed data. This is called implicitly at instantiation time.

`HTMLParser.getpos()`

Return current line number and offset.

`HTMLParser.get_starttag_text()`

Return the text of the most recently opened start tag. This should not normally be needed for structured processing, but may be useful in dealing with HTML “as deployed” or for re-generating input with minimal changes (whitespace between attributes can be preserved, etc.).

The following methods are called when data or markup elements are encountered and they are meant to be overridden in a subclass. The base class implementations do nothing (except for `handle_startendtag()`):

`HTMLParser.handle_starttag(tag, attrs)`

This method is called to handle the start of a tag (e.g. `<div id="main">`).

The *tag* argument is the name of the tag converted to lower case. The *attrs* argument is a list of (*name*, *value*) pairs containing the attributes found inside the tag’s `<>` brackets. The *name* will be translated to lower case, and quotes in the *value* have been removed, and character and entity references have been replaced.

For instance, for the tag `<A HREF="http://www.cwi.nl/">`, this method would be called as `handle_starttag('a', [('href', 'http://www.cwi.nl/')])`. Changed in version 2.6: All entity references from `htmlentitydefs` are now replaced in the attribute values.

`HTMLParser.handle_endtag(tag)`

This method is called to handle the end tag of an element (e.g. `</div>`).

The *tag* argument is the name of the tag converted to lower case.

`HTMLParser.handle_startendtag(tag, attrs)`

Similar to `handle_starttag()`, but called when the parser encounters an XHTML-style empty tag (`<img ... />`). This method may be overridden by subclasses which require this particular lexical information; the default implementation simply calls `handle_starttag()` and `handle_endtag()`.

`HTMLParser.handle_data(data)`

This method is called to process arbitrary data (e.g. text nodes and the content of `<script>...</script>` and `<style>...</style>`).

`HTMLParser.handle_entityref(name)`

This method is called to process a named character reference of the form `&name;` (e.g. `&gt;`), where *name* is a general entity reference (e.g. `'gt'`).

`HTMLParser.handle_charref(name)`

This method is called to process decimal and hexadecimal numeric character references of the form `&#NNN;` and `&#xNNN;`. For example, the decimal equivalent for `&gt;` is `&#62;`, whereas the hexadecimal is `&#x3E;`; in this case the method will receive `'62'` or `'x3E'`.

`HTMLParser.handle_comment(data)`

This method is called when a comment is encountered (e.g. `<!--comment-->`).

For example, the comment `<!-- comment -->` will cause this method to be called with the argument `'comment'`.

The content of Internet Explorer conditional comments (condcoms) will also be sent to this method, so, for `<!--[if IE 9]>IE9-specific content<![endif]-->`, this method will receive `'[if IE 9]>IE-specific content<![endif]'`.

`HTMLParser.handle_decl(decl)`

This method is called to handle an HTML doctype declaration (e.g. `<!DOCTYPE html>`).

The *decl* parameter will be the entire contents of the declaration inside the `<! . . . >` markup (e.g. `' DOCTYPE html'`).

`HTMLParser.handle_pi` (*data*)

This method is called when a processing instruction is encountered. The *data* parameter will contain the entire processing instruction. For example, for the processing instruction `<?proc color=' red' >`, this method would be called as `handle_pi("proc color=' red' ")`.

---

**Note:** The `HTMLParser` class uses the SGML syntactic rules for processing instructions. An XHTML processing instruction using the trailing `' ?'` will cause the `' ?'` to be included in *data*.

---

`HTMLParser.unknown_decl` (*data*)

This method is called when an unrecognized declaration is read by the parser.

The *data* parameter will be the entire contents of the declaration inside the `<! [ . . . ] >` markup. It is sometimes useful to be overridden by a derived class.

### 19.1.3 Examples

The following class implements a parser that will be used to illustrate more examples:

```
from HTMLParser import HTMLParser
from htmlentitydefs import name2codepoint
```

```
class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print "Start tag:", tag
        for attr in attrs:
            print "    attr:", attr
    def handle_endtag(self, tag):
        print "End tag  :", tag
    def handle_data(self, data):
        print "Data     :", data
    def handle_comment(self, data):
        print "Comment  :", data
    def handle_entityref(self, name):
        c = unichr(name2codepoint[name])
        print "Named ent:", c
    def handle_charref(self, name):
        if name.startswith('x'):
            c = unichr(int(name[1:], 16))
        else:
            c = unichr(int(name))
        print "Num ent  :", c
    def handle_decl(self, data):
        print "Decl     :", data
```

```
parser = MyHTMLParser()
```

Parsing a doctype:

```
>>> parser.feed('<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN" '
...           '<"http://www.w3.org/TR/html4/strict.dtd">')
Decl      : DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN" "http://www.w3.org/TR/html4/str
```

Parsing an element with a few attributes and a title:

```
>>> parser.feed('')
Start tag: img
      attr: ('src', 'python-logo.png')
      attr: ('alt', 'The Python logo')
>>>
>>> parser.feed('<h1>Python</h1>')
Start tag: h1
Data      : Python
End tag   : h1
```

The content of script and style elements is returned as is, without further parsing:

```
>>> parser.feed('<style type="text/css">#python { color: green }</style>')
Start tag: style
      attr: ('type', 'text/css')
Data      : #python { color: green }
End tag   : style
>>>
>>> parser.feed('<script type="text/javascript">'
...           'alert("<strong>hello!</strong>");</script>')
Start tag: script
      attr: ('type', 'text/javascript')
Data      : alert("<strong>hello!</strong>");
End tag   : script
```

Parsing comments:

```
>>> parser.feed('<!-- a comment -->'
...           '<!--[if IE 9]>IE-specific content<![endif]-->')
Comment   : a comment
Comment   : [if IE 9]>IE-specific content<![endif]
```

Parsing named and numeric character references and converting them to the correct char (note: these 3 references are all equivalent to '>'):

```
>>> parser.feed('&gt;&#62;&#x3E;')
Named ent: >
Num ent   : >
Num ent   : >
```

Feeding incomplete chunks to `feed()` works, but `handle_data()` might be called more than once:

```
>>> for chunk in ['<sp', 'an>buff', 'ered', 'text</s', 'pan>']:
...     parser.feed(chunk)
...
Start tag: span
Data      : buff
Data      : ered
Data      : text
End tag   : span
```

Parsing invalid HTML (e.g. unquoted attributes) also works:

```
>>> parser.feed('<p><a class=link href=#main>tag soup</p ></a>')
Start tag: p
Start tag: a
      attr: ('class', 'link')
```

```
    attr: ('href', '#main')
Data      : tag soup
End tag   : p
End tag   : a
```

## 19.2 sgmllib — Simple SGML parser

Deprecated since version 2.6: The `sgmllib` module has been removed in Python 3. This module defines a class `SGMLParser` which serves as the basis for parsing text files formatted in SGML (Standard Generalized Markup Language). In fact, it does not provide a full SGML parser — it only parses SGML insofar as it is used by HTML, and the module only exists as a base for the `htmllib` module. Another HTML parser which supports XHTML and offers a somewhat different interface is available in the `HTMLParser` module.

### class `sgmllib.SGMLParser`

The `SGMLParser` class is instantiated without arguments. The parser is hardcoded to recognize the following constructs:

- Opening and closing tags of the form `<tag attr="value" ...>` and `</tag>`, respectively.
- Numeric character references of the form `&#name;`.
- Entity references of the form `&name;`.
- SGML comments of the form `<!--text-->`. Note that spaces, tabs, and newlines are allowed between the trailing `>` and the immediately preceding `--`.

A single exception is defined as well:

### exception `sgmllib.SGMLParseError`

Exception raised by the `SGMLParser` class when it encounters an error while parsing. New in version 2.1.

`SGMLParser` instances have the following methods:

#### `SGMLParser.reset()`

Reset the instance. Loses all unprocessed data. This is called implicitly at instantiation time.

#### `SGMLParser.setnomoretags()`

Stop processing tags. Treat all following input as literal input (CDATA). (This is only provided so the HTML tag `<PLAINTEXT>` can be implemented.)

#### `SGMLParser.setliteral()`

Enter literal mode (CDATA mode).

#### `SGMLParser.feed(data)`

Feed some text to the parser. It is processed insofar as it consists of complete elements; incomplete data is buffered until more data is fed or `close()` is called.

#### `SGMLParser.close()`

Force processing of all buffered data as if it were followed by an end-of-file mark. This method may be redefined by a derived class to define additional processing at the end of the input, but the redefined version should always call `close()`.

#### `SGMLParser.get_starttag_text()`

Return the text of the most recently opened start tag. This should not normally be needed for structured processing, but may be useful in dealing with HTML “as deployed” or for re-generating input with minimal changes (whitespace between attributes can be preserved, etc.).

#### `SGMLParser.handle_starttag(tag, method, attributes)`

This method is called to handle start tags for which either a `start_tag()` or `do_tag()` method has been defined. The `tag` argument is the name of the tag converted to lower case, and the `method` argument is the bound

method which should be used to support semantic interpretation of the start tag. The *attributes* argument is a list of (*name*, *value*) pairs containing the attributes found inside the tag's <> brackets.

The *name* has been translated to lower case. Double quotes and backslashes in the *value* have been interpreted, as well as known character references and known entity references terminated by a semicolon (normally, entity references can be terminated by any non-alphanumerical character, but this would break the very common case of <A HREF="url?spam=1&eggs=2"> when *eggs* is a valid entity name).

For instance, for the tag <A HREF="http://www.cwi.nl/">, this method would be called as `unknown_starttag('a', [('href', 'http://www.cwi.nl/')])`. The base implementation simply calls *method* with *attributes* as the only argument. New in version 2.5: Handling of entity and character references within attribute values.

`SGMLParser.handle_endtag` (*tag*, *method*)

This method is called to handle endtags for which an `end_tag()` method has been defined. The *tag* argument is the name of the tag converted to lower case, and the *method* argument is the bound method which should be used to support semantic interpretation of the end tag. If no `end_tag()` method is defined for the closing element, this handler is not called. The base implementation simply calls *method*.

`SGMLParser.handle_data` (*data*)

This method is called to process arbitrary data. It is intended to be overridden by a derived class; the base class implementation does nothing.

`SGMLParser.handle_charref` (*ref*)

This method is called to process a character reference of the form `&#ref;`. The base implementation uses `convert_charref()` to convert the reference to a string. If that method returns a string, it is passed to `handle_data()`, otherwise `unknown_charref(ref)` is called to handle the error. Changed in version 2.5: Use `convert_charref()` instead of hard-coding the conversion.

`SGMLParser.convert_charref` (*ref*)

Convert a character reference to a string, or `None`. *ref* is the reference passed in as a string. In the base implementation, *ref* must be a decimal number in the range 0-255. It converts the code point found using the `convert_codepoint()` method. If *ref* is invalid or out of range, this method returns `None`. This method is called by the default `handle_charref()` implementation and by the attribute value parser. New in version 2.5.

`SGMLParser.convert_codepoint` (*codepoint*)

Convert a codepoint to a `str` value. Encodings can be handled here if appropriate, though the rest of `sgmlib` is oblivious on this matter. New in version 2.5.

`SGMLParser.handle_entityref` (*ref*)

This method is called to process a general entity reference of the form `&ref;` where *ref* is an general entity reference. It converts *ref* by passing it to `convert_entityref()`. If a translation is returned, it calls the method `handle_data()` with the translation; otherwise, it calls the method `unknown_entityref(ref)`. The default `entitydefs` defines translations for `&amp;`, `&apos;`, `&gt;`, `&lt;`, and `&quot;`. Changed in version 2.5: Use `convert_entityref()` instead of hard-coding the conversion.

`SGMLParser.convert_entityref` (*ref*)

Convert a named entity reference to a `str` value, or `None`. The resulting value will not be parsed. *ref* will be only the name of the entity. The default implementation looks for *ref* in the instance (or class) variable `entitydefs` which should be a mapping from entity names to corresponding translations. If no translation is available for *ref*, this method returns `None`. This method is called by the default `handle_entityref()` implementation and by the attribute value parser. New in version 2.5.

`SGMLParser.handle_comment` (*comment*)

This method is called when a comment is encountered. The *comment* argument is a string containing the text between the `<!--` and `-->` delimiters, but not the delimiters themselves. For example, the comment `<!--text-->` will cause this method to be called with the argument `'text'`. The default method does nothing.

`SGMLParser.handle_decl` (*data*)

Method called when an SGML declaration is read by the parser. In practice, the `DOCTYPE` declaration is the only thing observed in HTML, but the parser does not discriminate among different (or broken) declarations. Internal subsets in a `DOCTYPE` declaration are not supported. The *data* parameter will be the entire contents of the declaration inside the `<!...>` markup. The default implementation does nothing.

`SGMLParser.report_unbalanced` (*tag*)

This method is called when an end tag is found which does not correspond to any open element.

`SGMLParser.unknown_starttag` (*tag*, *attributes*)

This method is called to process an unknown start tag. It is intended to be overridden by a derived class; the base class implementation does nothing.

`SGMLParser.unknown_endtag` (*tag*)

This method is called to process an unknown end tag. It is intended to be overridden by a derived class; the base class implementation does nothing.

`SGMLParser.unknown_charref` (*ref*)

This method is called to process unresolvable numeric character references. Refer to `handle_charref()` to determine what is handled by default. It is intended to be overridden by a derived class; the base class implementation does nothing.

`SGMLParser.unknown_entityref` (*ref*)

This method is called to process an unknown entity reference. It is intended to be overridden by a derived class; the base class implementation does nothing.

Apart from overriding or extending the methods listed above, derived classes may also define methods of the following form to define processing of specific tags. Tag names in the input stream are case independent; the *tag* occurring in method names must be in lower case:

`SGMLParser.start_tag` (*attributes*)

This method is called to process an opening tag *tag*. It has preference over `do_tag()`. The *attributes* argument has the same meaning as described for `handle_starttag()` above.

`SGMLParser.do_tag` (*attributes*)

This method is called to process an opening tag *tag* for which no `start_tag()` method is defined. The *attributes* argument has the same meaning as described for `handle_starttag()` above.

`SGMLParser.end_tag` ()

This method is called to process a closing tag *tag*.

Note that the parser maintains a stack of open elements for which no end tag has been found yet. Only tags processed by `start_tag()` are pushed on this stack. Definition of an `end_tag()` method is optional for these tags. For tags processed by `do_tag()` or by `unknown_tag()`, no `end_tag()` method must be defined; if defined, it will not be used. If both `start_tag()` and `do_tag()` methods exist for a tag, the `start_tag()` method takes precedence.

## 19.3 `htmllib` — A parser for HTML documents

Deprecated since version 2.6: The `htmllib` module has been removed in Python 3. This module defines a class which can serve as a base for parsing text files formatted in the HyperText Mark-up Language (HTML). The class is not directly concerned with I/O — it must be provided with input in string form via a method, and makes calls to methods of a “formatter” object in order to produce output. The `HTMLParser` class is designed to be used as a base class for other classes in order to add functionality, and allows most of its methods to be extended or overridden. In turn, this class is derived from and extends the `SGMLParser` class defined in module `sgmlib`. The `HTMLParser` implementation supports the HTML 2.0 language as described in [RFC 1866](#). Two implementations of formatter objects are provided in the `formatter` module; refer to the documentation for that module for information on the formatter interface.

The following is a summary of the interface defined by `sgmllib.SGMLParser`:

- The interface to feed data to an instance is through the `feed()` method, which takes a string argument. This can be called with as little or as much text at a time as desired; `p.feed(a)`; `p.feed(b)` has the same effect as `p.feed(a+b)`. When the data contains complete HTML markup constructs, these are processed immediately; incomplete constructs are saved in a buffer. To force processing of all unprocessed data, call the `close()` method.

For example, to parse the entire contents of a file, use:

```
parser.feed(open('myfile.html').read())
parser.close()
```

- The interface to define semantics for HTML tags is very simple: derive a class and define methods called `start_tag()`, `end_tag()`, or `do_tag()`. The parser will call these at appropriate moments: `start_tag()` or `do_tag()` is called when an opening tag of the form `<tag ...>` is encountered; `end_tag()` is called when a closing tag of the form `</tag>` is encountered. If an opening tag requires a corresponding closing tag, like `<H1> ... </H1>`, the class should define the `start_tag()` method; if a tag requires no closing tag, like `<P>`, the class should define the `do_tag()` method.

The module defines a parser class and an exception:

**class** `htmllib.HTMLParser` (*formatter*)

This is the basic HTML parser class. It supports all entity names required by the XHTML 1.0 Recommendation (<http://www.w3.org/TR/xhtml1>). It also defines handlers for all HTML 2.0 and many HTML 3.0 and 3.2 elements.

**exception** `htmllib.HTMLParseError`

Exception raised by the `HTMLParser` class when it encounters an error while parsing. New in version 2.4.

**See Also:**

**Module** `formatter` Interface definition for transforming an abstract flow of formatting events into specific output events on writer objects.

**Module** `HTMLParser` Alternate HTML parser that offers a slightly lower-level view of the input, but is designed to work with XHTML, and does not implement some of the SGML syntax not used in “HTML as deployed” and which isn’t legal for XHTML.

**Module** `htmlentitydefs` Definition of replacement text for XHTML 1.0 entities.

**Module** `sgmlib` Base class for `HTMLParser`.

### 19.3.1 HTMLParser Objects

In addition to tag methods, the `HTMLParser` class provides some additional methods and instance variables for use within tag methods.

`HTMLParser.formatter`

This is the formatter instance associated with the parser.

`HTMLParser.nofill`

Boolean flag which should be true when whitespace should not be collapsed, or false when it should be. In general, this should only be true when character data is to be treated as “preformatted” text, as within a `<PRE>` element. The default value is false. This affects the operation of `handle_data()` and `save_end()`.

`HTMLParser.anchor_bgn` (*href, name, type*)

This method is called at the start of an anchor region. The arguments correspond to the attributes of the `<A>` tag with the same names. The default implementation maintains a list of hyperlinks (defined by the `HREF` attribute for `<A>` tags) within the document. The list of hyperlinks is available as the data attribute `anchorlist`.

`HTMLParser.anchor_end()`

This method is called at the end of an anchor region. The default implementation adds a textual footnote marker using an index into the list of hyperlinks created by `anchor_bgn()`.

`HTMLParser.handle_image(source, alt[, ismap[, align[, width[, height]]]])`

This method is called to handle images. The default implementation simply passes the `alt` value to the `handle_data()` method.

`HTMLParser.save_bgn()`

Begins saving character data in a buffer instead of sending it to the formatter object. Retrieve the stored data via `save_end()`. Use of the `save_bgn()` / `save_end()` pair may not be nested.

`HTMLParser.save_end()`

Ends buffering character data and returns all data saved since the preceding call to `save_bgn()`. If the `nofill` flag is false, whitespace is collapsed to single spaces. A call to this method without a preceding call to `save_bgn()` will raise a `TypeError` exception.

## 19.4 `htmlentitydefs` — Definitions of HTML general entities

---

**Note:** The `htmlentitydefs` module has been renamed to `html.entities` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

**Source code:** [Lib/htmlentitydefs.py](#)

---

This module defines three dictionaries, `name2codepoint`, `codepoint2name`, and `entitydefs`. `entitydefs` is used by the `htmllib` module to provide the `entitydefs` attribute of the `HTMLParser` class. The definition provided here contains all the entities defined by XHTML 1.0 that can be handled using simple textual substitution in the Latin-1 character set (ISO-8859-1).

`htmlentitydefs.entitydefs`

A dictionary mapping XHTML 1.0 entity definitions to their replacement text in ISO Latin-1.

`htmlentitydefs.name2codepoint`

A dictionary that maps HTML entity names to the Unicode codepoints. New in version 2.3.

`htmlentitydefs.codepoint2name`

A dictionary that maps Unicode codepoints to HTML entity names. New in version 2.3.

## 19.5 `xml.etree.ElementTree` — The ElementTree XML API

New in version 2.5. **Source code:** [Lib/xml/etree/ElementTree.py](#)

---

The `Element` type is a flexible container object, designed to store hierarchical data structures in memory. The type can be described as a cross between a list and a dictionary.

Each element has a number of properties associated with it:

- a tag which is a string identifying what kind of data this element represents (the element type, in other words).
- a number of attributes, stored in a Python dictionary.
- a text string.

- an optional tail string.
- a number of child elements, stored in a Python sequence

To create an element instance, use the `Element` constructor or the `SubElement()` factory function.

The `ElementTree` class can be used to wrap an element structure, and convert it from and to XML.

A C implementation of this API is available as `xml.etree.cElementTree`.

See <http://effbot.org/zone/element-index.htm> for tutorials and links to other docs. Fredrik Lundh's page is also the location of the development version of the `xml.etree.ElementTree`. Changed in version 2.7: The `ElementTree` API is updated to 1.3. For more information, see [Introducing ElementTree 1.3](#).

## 19.5.1 Tutorial

This is a short tutorial for using `xml.etree.ElementTree` (ET in short). The goal is to demonstrate some of the building blocks and basic concepts of the module.

### XML tree and elements

XML is an inherently hierarchical data format, and the most natural way to represent it is with a tree. ET has two classes for this purpose - `ElementTree` represents the whole XML document as a tree, and `Element` represents a single node in this tree. Interactions with the whole document (reading and writing to/from files) are usually done on the `ElementTree` level. Interactions with a single XML element and its sub-elements are done on the `Element` level.

### Parsing XML

We'll be using the following XML document as the sample data for this section:

```
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank>1</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank>4</rank>
    <year>2011</year>
    <gdppc>59900</gdppc>
    <neighbor name="Malaysia" direction="N"/>
  </country>
  <country name="Panama">
    <rank>68</rank>
    <year>2011</year>
    <gdppc>13600</gdppc>
    <neighbor name="Costa Rica" direction="W"/>
    <neighbor name="Colombia" direction="E"/>
  </country>
</data>
```

We have a number of ways to import the data. Reading the file from disk:

```
import xml.etree.ElementTree as ET
tree = ET.parse('country_data.xml')
root = tree.getroot()
```

Reading the data from a string:

```
root = ET.fromstring(country_data_as_string)
```

`fromstring()` parses XML from a string directly into an `Element`, which is the root element of the parsed tree. Other parsing functions may create an `ElementTree`. Check the documentation to be sure.

As an `Element`, `root` has a tag and a dictionary of attributes:

```
>>> root.tag
'data'
>>> root.attrib
{}
```

It also has children nodes over which we can iterate:

```
>>> for child in root:
...     print child.tag, child.attrib
...
country {'name': 'Liechtenstein'}
country {'name': 'Singapore'}
country {'name': 'Panama'}
```

Children are nested, and we can access specific child nodes by index:

```
>>> root[0][1].text
'2008'
```

### Finding interesting elements

`Element` has some useful methods that help iterate recursively over all the sub-tree below it (its children, their children, and so on). For example, `Element.iter()`:

```
>>> for neighbor in root.iter('neighbor'):
...     print neighbor.attrib
...
{'name': 'Austria', 'direction': 'E'}
{'name': 'Switzerland', 'direction': 'W'}
{'name': 'Malaysia', 'direction': 'N'}
{'name': 'Costa Rica', 'direction': 'W'}
{'name': 'Colombia', 'direction': 'E'}
```

`Element.findall()` finds only elements with a tag which are direct children of the current element. `Element.find()` finds the *first* child with a particular tag, and `Element.text()` accesses the element's text content. `Element.get()` accesses the element's attributes:

```
>>> for country in root.findall('country'):
...     rank = country.find('rank').text
...     name = country.get('name')
...     print name, rank
...
Liechtenstein 1
Singapore 4
Panama 68
```

More sophisticated specification of which elements to look for is possible by using *XPath*.

## Modifying an XML File

`ElementTree` provides a simple way to build XML documents and write them to files. The `ElementTree.write()` method serves this purpose.

Once created, an `Element` object may be manipulated by directly changing its fields (such as `Element.text`), adding and modifying attributes (`Element.set()` method), as well as adding new children (for example with `Element.append()`).

Let's say we want to add one to each country's rank, and add an updated attribute to the rank element:

```
>>> for rank in root.iter('rank'):
...     new_rank = int(rank.text) + 1
...     rank.text = str(new_rank)
...     rank.set('updated', 'yes')
...
>>> tree.write('output.xml')
```

Our XML now looks like this:

```
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank updated="yes">2</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank updated="yes">5</rank>
    <year>2011</year>
    <gdppc>59900</gdppc>
    <neighbor name="Malaysia" direction="N"/>
  </country>
  <country name="Panama">
    <rank updated="yes">69</rank>
    <year>2011</year>
    <gdppc>13600</gdppc>
    <neighbor name="Costa Rica" direction="W"/>
    <neighbor name="Colombia" direction="E"/>
  </country>
</data>
```

We can remove elements using `Element.remove()`. Let's say we want to remove all countries with a rank higher than 50:

```
>>> for country in root.findall('country'):
...     rank = int(country.find('rank').text)
...     if rank > 50:
...         root.remove(country)
...
>>> tree.write('output.xml')
```

Our XML now looks like this:

```
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank updated="yes">2</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank updated="yes">5</rank>
    <year>2011</year>
    <gdppc>59900</gdppc>
    <neighbor name="Malaysia" direction="N"/>
  </country>
</data>
```

### Building XML documents

The `SubElement()` function also provides a convenient way to create new sub-elements for a given element:

```
>>> a = ET.Element('a')
>>> b = ET.SubElement(a, 'b')
>>> c = ET.SubElement(a, 'c')
>>> d = ET.SubElement(c, 'd')
>>> ET.dump(a)
<a><b /><c><d /></c></a>
```

### Additional resources

See <http://effbot.org/zone/element-index.htm> for tutorials and links to other docs.

## 19.5.2 XPath support

This module provides limited support for [XPath expressions](#) for locating elements in a tree. The goal is to support a small subset of the abbreviated syntax; a full XPath engine is outside the scope of the module.

### Example

Here's an example that demonstrates some of the XPath capabilities of the module. We'll be using the `countrydata` XML document from the *Parsing XML* section:

```
import xml.etree.ElementTree as ET
```

```
root = ET.fromstring(countrydata)
```

```
# Top-level elements
root.findall(".")
```

```
# All 'neighbor' grand-children of 'country' children of the top-level
# elements
root.findall("./country/neighbor")
```

```
# Nodes with name='Singapore' that have a 'year' child
root.findall("./year/..[@name='Singapore']")

# 'year' nodes that are children of nodes with name='Singapore'
root.findall("./*[@name='Singapore']/year")

# All 'neighbor' nodes that are the second child of their parent
root.findall("./neighbor[2]")
```

## Supported XPath syntax

Syntax	Meaning
tag	Selects all child elements with the given tag. For example, spam selects all child elements named spam, spam/egg selects all grandchildren named egg in all children named spam.
*	Selects all child elements. For example, */egg selects all grandchildren named egg.
.	Selects the current node. This is mostly useful at the beginning of the path, to indicate that it's a relative path.
//	Selects all subelements, on all levels beneath the current element. For example, ./egg selects all egg elements in the entire tree.
..	Selects the parent element.
[@attrib]	Selects all elements that have the given attribute.
[@attrib='value']	Selects all elements for which the given attribute has the given value. The value cannot contain quotes.
[tag]	Selects all elements that have a child named tag. Only immediate children are supported.
[position]	Selects all elements that are located at the given position. The position can be either an integer (1 is the first position), the expression last() (for the last position), or a position relative to the last position (e.g. last()-1).

Predicates (expressions within square brackets) must be preceded by a tag name, an asterisk, or another predicate. position predicates must be preceded by a tag name.

## 19.5.3 Reference

### Functions

`xml.etree.ElementTree.Comment` (*text=None*)

Comment element factory. This factory function creates a special element that will be serialized as an XML comment by the standard serializer. The comment string can be either a bytestring or a Unicode string. *text* is a string containing the comment string. Returns an element instance representing a comment.

`xml.etree.ElementTree.dump` (*elem*)

Writes an element tree or element structure to `sys.stdout`. This function should be used for debugging only.

The exact output format is implementation dependent. In this version, it's written as an ordinary XML file.

*elem* is an element tree or an individual element.

`xml.etree.ElementTree.fromstring` (*text*)

Parses an XML section from a string constant. Same as `XML()`. *text* is a string containing XML data. Returns an `Element` instance.

`xml.etree.ElementTree.fromstringlist` (*sequence, parser=None*)

Parses an XML document from a sequence of string fragments. *sequence* is a list or other sequence containing

XML data fragments. *parser* is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns an `Element` instance. New in version 2.7.

`xml.etree.ElementTree.iselement` (*element*)

Checks if an object appears to be a valid element object. *element* is an element instance. Returns a true value if this is an element object.

`xml.etree.ElementTree.iterparse` (*source*, *events=None*, *parser=None*)

Parses an XML section into an element tree incrementally, and reports what's going on to the user. *source* is a filename or file object containing XML data. *events* is a list of events to report back. If omitted, only "end" events are reported. *parser* is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns an *iterator* providing (*event*, *elem*) pairs.

---

**Note:** `iterparse()` only guarantees that it has seen the ">" character of a starting tag when it emits a "start" event, so the attributes are defined, but the contents of the text and tail attributes are undefined at that point. The same applies to the element children; they may or may not be present.

If you need a fully populated element, look for "end" events instead.

---

`xml.etree.ElementTree.parse` (*source*, *parser=None*)

Parses an XML section into an element tree. *source* is a filename or file object containing XML data. *parser* is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns an `ElementTree` instance.

`xml.etree.ElementTree.ProcessingInstruction` (*target*, *text=None*)

PI element factory. This factory function creates a special element that will be serialized as an XML processing instruction. *target* is a string containing the PI target. *text* is a string containing the PI contents, if given. Returns an element instance, representing a processing instruction.

`xml.etree.ElementTree.register_namespace` (*prefix*, *uri*)

Registers a namespace prefix. The registry is global, and any existing mapping for either the given prefix or the namespace URI will be removed. *prefix* is a namespace prefix. *uri* is a namespace uri. Tags and attributes in this namespace will be serialized with the given prefix, if at all possible. New in version 2.7.

`xml.etree.ElementTree.SubElement` (*parent*, *tag*, *attrib={}*, *\*\*extra*)

Subelement factory. This function creates an element instance, and appends it to an existing element.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. *parent* is the parent element. *tag* is the subelement name. *attrib* is an optional dictionary, containing element attributes. *extra* contains additional attributes, given as keyword arguments. Returns an element instance.

`xml.etree.ElementTree.tostring` (*element*, *encoding="us-ascii"*, *method="xml"*)

Generates a string representation of an XML element, including all subelements. *element* is an `Element` instance. *encoding*<sup>1</sup> is the output encoding (default is US-ASCII). *method* is either "xml", "html" or "text" (default is "xml"). Returns an encoded string containing the XML data.

`xml.etree.ElementTree.tostringlist` (*element*, *encoding="us-ascii"*, *method="xml"*)

Generates a string representation of an XML element, including all subelements. *element* is an `Element` instance. *encoding*<sup>1</sup> is the output encoding (default is US-ASCII). *method* is either "xml", "html" or "text" (default is "xml"). Returns a list of encoded strings containing the XML data. It does not guarantee any specific sequence, except that `"".join(tostringlist(element)) == tostring(element)`. New in version 2.7.

`xml.etree.ElementTree.XML` (*text*, *parser=None*)

Parses an XML section from a string constant. This function can be used to embed "XML literals" in Python

---

<sup>1</sup> The encoding string included in XML output should conform to the appropriate standards. For example, "UTF-8" is valid, but "UTF8" is not. See <http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl> and <http://www.iana.org/assignments/character-sets>.

code. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns an `Element` instance.

`xml.etree.ElementTree.XMLID(text, parser=None)`

Parses an XML section from a string constant, and also returns a dictionary which maps from element id:s to elements. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns a tuple containing an `Element` instance and a dictionary.

## Element Objects

**class** `xml.etree.ElementTree.Element(tag, attrib={}, **extra)`

Element class. This class defines the Element interface, and provides a reference implementation of this interface.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. *tag* is the element name. *attrib* is an optional dictionary, containing element attributes. *extra* contains additional attributes, given as keyword arguments.

### **tag**

A string identifying what kind of data this element represents (the element type, in other words).

### **text**

The *text* attribute can be used to hold additional data associated with the element. As the name implies this attribute is usually a string but may be any application-specific object. If the element is created from an XML file the attribute will contain any text found between the element tags.

### **tail**

The *tail* attribute can be used to hold additional data associated with the element. This attribute is usually a string but may be any application-specific object. If the element is created from an XML file the attribute will contain any text found after the element's end tag and before the next tag.

### **attrib**

A dictionary containing the element's attributes. Note that while the *attrib* value is always a real mutable Python dictionary, an `ElementTree` implementation may choose to use another internal representation, and create the dictionary only if someone asks for it. To take advantage of such implementations, use the dictionary methods below whenever possible.

The following dictionary-like methods work on the element attributes.

### **clear()**

Resets an element. This function removes all subelements, clears all attributes, and sets the text and tail attributes to None.

### **get(*key*, *default=None*)**

Gets the element attribute named *key*.

Returns the attribute value, or *default* if the attribute was not found.

### **items()**

Returns the element attributes as a sequence of (name, value) pairs. The attributes are returned in an arbitrary order.

### **keys()**

Returns the elements attribute names as a list. The names are returned in an arbitrary order.

### **set(*key*, *value*)**

Set the attribute *key* on the element to *value*.

The following methods work on the element's children (subelements).

**append** (*subelement*)

Adds the element *subelement* to the end of this element's internal list of subelements.

**extend** (*subelements*)

Appends *subelements* from a sequence object with zero or more elements. Raises `AssertionError` if a subelement is not a valid object. New in version 2.7.

**find** (*match*)

Finds the first subelement matching *match*. *match* may be a tag name or path. Returns an element instance or `None`.

**findall** (*match*)

Finds all matching subelements, by tag name or path. Returns a list containing all matching elements in document order.

**findtext** (*match*, *default=None*)

Finds text for the first subelement matching *match*. *match* may be a tag name or path. Returns the text content of the first matching element, or *default* if no element was found. Note that if the matching element has no text content an empty string is returned.

**getchildren** ()

Deprecated since version 2.7: Use `list(elem)` or iteration.

**getiterator** (*tag=None*)

Deprecated since version 2.7: Use method `Element.iter()` instead.

**insert** (*index*, *element*)

Inserts a subelement at the given position in this element.

**iter** (*tag=None*)

Creates a tree *iterator* with the current element as the root. The iterator iterates over this element and all elements below it, in document (depth first) order. If *tag* is not `None` or `'*'`, only elements whose tag equals *tag* are returned from the iterator. If the tree structure is modified during iteration, the result is undefined. New in version 2.7.

**iterfind** (*match*)

Finds all matching subelements, by tag name or path. Returns an iterable yielding all matching elements in document order. New in version 2.7.

**itertext** ()

Creates a text iterator. The iterator loops over this element and all subelements, in document order, and returns all inner text. New in version 2.7.

**makeelement** (*tag*, *attrib*)

Creates a new element object of the same type as this element. Do not call this method, use the `SubElement()` factory function instead.

**remove** (*subelement*)

Removes *subelement* from the element. Unlike the `find*` methods this method compares elements based on the instance identity, not on tag value or contents.

`Element` objects also support the following sequence type methods for working with subelements: `__delitem__()`, `__getitem__()`, `__setitem__()`, `__len__()`.

Caution: Elements with no subelements will test as `False`. This behavior will change in future versions. Use specific `len(elem)` or `elem is None` test instead.

```
element = root.find('foo')
```

```
if not element: # careful!
    print "element not found, or element has no subelements"
```

```
if element is None:
    print "element not found"
```

## ElementTree Objects

**class** `xml.etree.ElementTree.ElementTree` (*element=None, file=None*)

ElementTree wrapper class. This class represents an entire element hierarchy, and adds some extra support for serialization to and from standard XML.

*element* is the root element. The tree is initialized with the contents of the XML *file* if given.

**\_setroot** (*element*)

Replaces the root element for this tree. This discards the current contents of the tree, and replaces it with the given element. Use with care. *element* is an element instance.

**find** (*match*)

Finds the first toplevel element matching *match*. *match* may be a tag name or path. Same as `getroot().find(match)`. Returns the first matching element, or `None` if no element was found.

**findall** (*match*)

Finds all matching subelements, by tag name or path. Same as `getroot().findall(match)`. *match* may be a tag name or path. Returns a list containing all matching elements, in document order.

**findtext** (*match, default=None*)

Finds the element text for the first toplevel element with given tag. Same as `getroot().findtext(match)`. *match* may be a tag name or path. *default* is the value to return if the element was not found. Returns the text content of the first matching element, or the default value no element was found. Note that if the element is found, but has no text content, this method returns an empty string.

**getiterator** (*tag=None*)

Deprecated since version 2.7: Use method `ElementTree.iter()` instead.

**getroot** ()

Returns the root element for this tree.

**iter** (*tag=None*)

Creates and returns a tree iterator for the root element. The iterator loops over all elements in this tree, in section order. *tag* is the tag to look for (default is to return all elements)

**iterfind** (*match*)

Finds all matching subelements, by tag name or path. Same as `getroot().iterfind(match)`. Returns an iterable yielding all matching elements in document order. New in version 2.7.

**parse** (*source, parser=None*)

Loads an external XML section into this element tree. *source* is a file name or file object. *parser* is an optional parser instance. If not given, the standard XMLParser parser is used. Returns the section root element.

**write** (*file, encoding="us-ascii", xml\_declaration=None, method="xml"*)

Writes the element tree to a file, as XML. *file* is a file name, or a file object opened for writing. *encoding*<sup>1</sup> is the output encoding (default is US-ASCII). *xml\_declaration* controls if an XML declaration should be added to the file. Use `False` for never, `True` for always, `None` for only if not US-ASCII or UTF-8 (default is `None`). *method* is either `"xml"`, `"html"` or `"text"` (default is `"xml"`). Returns an encoded string.

This is the XML file that is going to be manipulated:

```
<html>
  <head>
    <title>Example page</title>
```

```
</head>
<body>
  <p>Moved to <a href="http://example.org/">example.org</a>
  or <a href="http://example.com/">example.com</a>.</p>
</body>
</html>
```

Example of changing the attribute “target” of every link in first paragraph:

```
>>> from xml.etree.ElementTree import ElementTree
>>> tree = ElementTree()
>>> tree.parse("index.xhtml")
<Element 'html' at 0xb77e6fac>
>>> p = tree.find("body/p")      # Finds first occurrence of tag p in body
>>> p
<Element 'p' at 0xb77ec26c>
>>> links = list(p.iter("a"))    # Returns list of all links
>>> links
[<Element 'a' at 0xb77ec2ac>, <Element 'a' at 0xb77ec1cc>]
>>> for i in links:              # Iterates through all found links
...     i.attrib["target"] = "blank"
>>> tree.write("output.xhtml")
```

### QName Objects

**class** `xml.etree.ElementTree.QName` (*text\_or\_uri*, *tag=None*)

QName wrapper. This can be used to wrap a QName attribute value, in order to get proper namespace handling on output. *text\_or\_uri* is a string containing the QName value, in the form {uri}local, or, if the tag argument is given, the URI part of a QName. If *tag* is given, the first argument is interpreted as an URI, and this argument is interpreted as a local name. QName instances are opaque.

### TreeBuilder Objects

**class** `xml.etree.ElementTree.TreeBuilder` (*element\_factory=None*)

Generic element structure builder. This builder converts a sequence of start, data, and end method calls to a well-formed element structure. You can use this class to build an element structure using a custom XML parser, or a parser for some other XML-like format. The *element\_factory* is called to create new `Element` instances when given.

**close** ()

Flushes the builder buffers, and returns the toplevel document element. Returns an `Element` instance.

**data** (*data*)

Adds text to the current element. *data* is a string. This should be either a bytestring, or a Unicode string.

**end** (*tag*)

Closes the current element. *tag* is the element name. Returns the closed element.

**start** (*tag*, *attrs*)

Opens a new element. *tag* is the element name. *attrs* is a dictionary containing element attributes. Returns the opened element.

In addition, a custom `TreeBuilder` object can provide the following method:

**doctype** (*name*, *pubid*, *system*)

Handles a doctype declaration. *name* is the doctype name. *pubid* is the public identifier. *system* is the system identifier. This method does not exist on the default `TreeBuilder` class. New in version 2.7.

## XMLParser Objects

**class** `xml.etree.ElementTree.XMLParser` (*html=0, target=None, encoding=None*)

Element structure builder for XML source data, based on the expat parser. *html* are predefined HTML entities. This flag is not supported by the current implementation. *target* is the target object. If omitted, the builder uses an instance of the standard `TreeBuilder` class. *encoding*<sup>1</sup> is optional. If given, the value overrides the encoding specified in the XML file.

**close** ()

Finishes feeding data to the parser. Returns an element structure.

**doctype** (*name, pubid, system*)

Deprecated since version 2.7: Define the `TreeBuilder.doctype()` method on a custom `TreeBuilder` target.

**feed** (*data*)

Feeds data to the parser. *data* is encoded data.

`XMLParser.feed()` calls *target*'s `start()` method for each opening tag, its `end()` method for each closing tag, and data is processed by method `data()`. `XMLParser.close()` calls *target*'s method `close()`. `XMLParser` can be used not only for building a tree structure. This is an example of counting the maximum depth of an XML file:

```
>>> from xml.etree.ElementTree import XMLParser
>>> class MaxDepth:                                # The target object of the parser
...     maxDepth = 0
...     depth = 0
...     def start(self, tag, attrib):             # Called for each opening tag.
...         self.depth += 1
...         if self.depth > self.maxDepth:
...             self.maxDepth = self.depth
...     def end(self, tag):                       # Called for each closing tag.
...         self.depth -= 1
...     def data(self, data):
...         pass                                  # We do not need to do anything with data.
...     def close(self):                         # Called when all data has been parsed.
...         return self.maxDepth
...
>>> target = MaxDepth()
>>> parser = XMLParser(target=target)
>>> exampleXml = """
... <a>
...   <b>
...   </b>
...   <b>
...     <c>
...     <d>
...     </d>
...     </c>
...   </b>
... </a>"""
>>> parser.feed(exampleXml)
>>> parser.close()
```

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## 19.6 `xml.dom` — The Document Object Model API

New in version 2.0. The Document Object Model, or “DOM,” is a cross-language API from the World Wide Web Consortium (W3C) for accessing and modifying XML documents. A DOM implementation presents an XML document as a tree structure, or allows client code to build such a structure from scratch. It then gives access to the structure through a set of objects which provided well-known interfaces.

The DOM is extremely useful for random-access applications. SAX only allows you a view of one bit of the document at a time. If you are looking at one SAX element, you have no access to another. If you are looking at a text node, you have no access to a containing element. When you write a SAX application, you need to keep track of your program’s position in the document somewhere in your own code. SAX does not do it for you. Also, if you need to look ahead in the XML document, you are just out of luck.

Some applications are simply impossible in an event driven model with no access to a tree. Of course you could build some sort of tree yourself in SAX events, but the DOM allows you to avoid writing that code. The DOM is a standard tree representation for XML data.

The Document Object Model is being defined by the W3C in stages, or “levels” in their terminology. The Python mapping of the API is substantially based on the DOM Level 2 recommendation.

DOM applications typically start by parsing some XML into a DOM. How this is accomplished is not covered at all by DOM Level 1, and Level 2 provides only limited improvements: There is a `DOMImplementation` object class which provides access to `Document` creation methods, but no way to access an XML reader/parser/Document builder in an implementation-independent way. There is also no well-defined way to access these methods without an existing `Document` object. In Python, each DOM implementation will provide a function `getDOMImplementation()`. DOM Level 3 adds a Load/Store specification, which defines an interface to the reader, but this is not yet available in the Python standard library.

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification; this portion of the reference manual describes the interpretation of the specification in Python.

The specification provided by the W3C defines the DOM API for Java, ECMAScript, and OMG IDL. The Python mapping defined here is based in large part on the IDL version of the specification, but strict compliance is not required (though implementations are free to support the strict mapping from IDL). See section *Conformance* for a detailed discussion of mapping requirements.

### See Also:

**Document Object Model (DOM) Level 2 Specification** The W3C recommendation upon which the Python DOM API is based.

**Document Object Model (DOM) Level 1 Specification** The W3C recommendation for the DOM supported by `xml.dom.minidom`.

**Python Language Mapping Specification** This specifies the mapping from OMG IDL to Python.

### 19.6.1 Module Contents

The `xml.dom` contains the following functions:

`xml.dom.registerDOMImplementation` (*name*, *factory*)

Register the *factory* function with the name *name*. The factory function should return an object which implements the `DOMImplementation` interface. The factory function can return the same object every time, or a new one for each call, as appropriate for the specific implementation (e.g. if that implementation supports some customization).

`xml.dom.getDOMImplementation([name[, features]])`

Return a suitable DOM implementation. The *name* is either well-known, the module name of a DOM implementation, or `None`. If it is not `None`, imports the corresponding module and returns a `DOMImplementation` object if the import succeeds. If no name is given, and if the environment variable

`PYTHON_DOM` is set, this variable is used to find the implementation.

If name is not given, this examines the available implementations to find one with the required feature set. If no implementation can be found, raise an `ImportError`. The features list must be a sequence of (*feature*, *version*) pairs which are passed to the `hasFeature()` method on available `DOMImplementation` objects.

Some convenience constants are also provided:

`xml.dom.EMPTY_NAMESPACE`

The value used to indicate that no namespace is associated with a node in the DOM. This is typically found as the `namespaceURI` of a node, or used as the *namespaceURI* parameter to a namespaces-specific method. New in version 2.2.

`xml.dom.XML_NAMESPACE`

The namespace URI associated with the reserved prefix `xml`, as defined by [Namespaces in XML](#) (section 4). New in version 2.2.

`xml.dom.XMLNS_NAMESPACE`

The namespace URI for namespace declarations, as defined by [Document Object Model \(DOM\) Level 2 Core Specification](#) (section 1.1.8). New in version 2.2.

`xml.dom.XHTML_NAMESPACE`

The URI of the XHTML namespace as defined by [XHTML 1.0: The Extensible HyperText Markup Language](#) (section 3.1.1). New in version 2.2.

In addition, `xml.dom` contains a base `Node` class and the DOM exception classes. The `Node` class provided by this module does not implement any of the methods or attributes defined by the DOM specification; concrete DOM implementations must provide those. The `Node` class provided as part of this module does provide the constants used for the `nodeType` attribute on concrete `Node` objects; they are located within the class rather than at the module level to conform with the DOM specifications.

## 19.6.2 Objects in the DOM

The definitive documentation for the DOM is the DOM specification from the W3C.

Note that DOM attributes may also be manipulated as nodes instead of as simple strings. It is fairly rare that you must do this, however, so this usage is not yet documented.

Interface	Section	Purpose
DOMImplementation	<i>DOMImplementation Objects</i>	Interface to the underlying implementation.
Node	<i>Node Objects</i>	Base interface for most objects in a document.
NodeList	<i>NodeList Objects</i>	Interface for a sequence of nodes.
DocumentType	<i>DocumentType Objects</i>	Information about the declarations needed to process a document.
Document	<i>Document Objects</i>	Object which represents an entire document.
Element	<i>Element Objects</i>	Element nodes in the document hierarchy.
Attr	<i>Attr Objects</i>	Attribute value nodes on element nodes.
Comment	<i>Comment Objects</i>	Representation of comments in the source document.
Text	<i>Text and CDATASection Objects</i>	Nodes containing textual content from the document.
ProcessingInstruction	<i>ProcessingInstruction Objects</i>	Processing instruction representation.

An additional section describes the exceptions defined for working with the DOM in Python.

## DOMImplementation Objects

The `DOMImplementation` interface provides a way for applications to determine the availability of particular features in the DOM they are using. DOM Level 2 added the ability to create new `Document` and `DocumentType` objects using the `DOMImplementation` as well.

`DOMImplementation.hasFeature` (*feature, version*)

Return true if the feature identified by the pair of strings *feature* and *version* is implemented.

`DOMImplementation.createDocument` (*namespaceUri, qualifiedName, doctype*)

Return a new `Document` object (the root of the DOM), with a child `Element` object having the given *namespaceUri* and *qualifiedName*. The *doctype* must be a `DocumentType` object created by `createDocumentType()`, or `None`. In the Python DOM API, the first two arguments can also be `None` in order to indicate that no `Element` child is to be created.

`DOMImplementation.createDocumentType` (*qualifiedName, publicId, systemId*)

Return a new `DocumentType` object that encapsulates the given *qualifiedName*, *publicId*, and *systemId* strings, representing the information contained in an XML document type declaration.

## Node Objects

All of the components of an XML document are subclasses of `Node`.

`Node.nodeType`

An integer representing the node type. Symbolic constants for the types are on the `Node` object: `ELEMENT_NODE`, `ATTRIBUTE_NODE`, `TEXT_NODE`, `CDATA_SECTION_NODE`, `ENTITY_NODE`, `PROCESSING_INSTRUCTION_NODE`, `COMMENT_NODE`, `DOCUMENT_NODE`, `DOCUMENT_TYPE_NODE`, `NOTATION_NODE`. This is a read-only attribute.

`Node.parentNode`

The parent of the current node, or `None` for the document node. The value is always a `Node` object or `None`. For `Element` nodes, this will be the parent element, except for the root element, in which case it will be the `Document` object. For `Attr` nodes, this is always `None`. This is a read-only attribute.

`Node.attributes`

A `NamedNodeMap` of attribute objects. Only elements have actual values for this; others provide `None` for this attribute. This is a read-only attribute.

**Node.previousSibling**

The node that immediately precedes this one with the same parent. For instance the element with an end-tag that comes just before the *self* element's start-tag. Of course, XML documents are made up of more than just elements so the previous sibling could be text, a comment, or something else. If this node is the first child of the parent, this attribute will be `None`. This is a read-only attribute.

**Node.nextSibling**

The node that immediately follows this one with the same parent. See also `previousSibling`. If this is the last child of the parent, this attribute will be `None`. This is a read-only attribute.

**Node.childNodes**

A list of nodes contained within this node. This is a read-only attribute.

**Node.firstChild**

The first child of the node, if there are any, or `None`. This is a read-only attribute.

**Node.lastChild**

The last child of the node, if there are any, or `None`. This is a read-only attribute.

**Node.localName**

The part of the `tagName` following the colon if there is one, else the entire `tagName`. The value is a string.

**Node.prefix**

The part of the `tagName` preceding the colon if there is one, else the empty string. The value is a string, or `None`.

**Node.namespaceURI**

The namespace associated with the element name. This will be a string or `None`. This is a read-only attribute.

**Node.nodeName**

This has a different meaning for each node type; see the DOM specification for details. You can always get the information you would get here from another property such as the `tagName` property for elements or the `name` property for attributes. For all node types, the value of this attribute will be either a string or `None`. This is a read-only attribute.

**Node.nodeValue**

This has a different meaning for each node type; see the DOM specification for details. The situation is similar to that with `nodeName`. The value is a string or `None`.

**Node.hasAttributes ()**

Returns true if the node has any attributes.

**Node.hasChildNodes ()**

Returns true if the node has any child nodes.

**Node.isSameNode (other)**

Returns true if *other* refers to the same node as this node. This is especially useful for DOM implementations which use any sort of proxy architecture (because more than one object can refer to the same node).

---

**Note:** This is based on a proposed DOM Level 3 API which is still in the “working draft” stage, but this particular interface appears uncontroversial. Changes from the W3C will not necessarily affect this method in the Python DOM interface (though any new W3C API for this would also be supported).

---

**Node.appendChild (newChild)**

Add a new child node to this node at the end of the list of children, returning *newChild*. If the node was already in in the tree, it is removed first.

**Node.insertBefore (newChild, refChild)**

Insert a new child node before an existing child. It must be the case that *refChild* is a child of this node; if

not, `ValueError` is raised. `newChild` is returned. If `refChild` is `None`, it inserts `newChild` at the end of the children's list.

`Node.removeChild(oldChild)`

Remove a child node. `oldChild` must be a child of this node; if not, `ValueError` is raised. `oldChild` is returned on success. If `oldChild` will not be used further, its `unlink()` method should be called.

`Node.replaceChild(newChild, oldChild)`

Replace an existing node with a new node. It must be the case that `oldChild` is a child of this node; if not, `ValueError` is raised.

`Node.normalize()`

Join adjacent text nodes so that all stretches of text are stored as single `Text` instances. This simplifies processing text from a DOM tree for many applications. New in version 2.1.

`Node.cloneNode(deep)`

Clone this node. Setting `deep` means to clone all child nodes as well. This returns the clone.

### NodeList Objects

A `NodeList` represents a sequence of nodes. These objects are used in two ways in the DOM Core recommendation: the `Element` objects provides one as its list of child nodes, and the `getElementsByTagName()` and `getElementsByTagNameNS()` methods of `Node` return objects with this interface to represent query results.

The DOM Level 2 recommendation defines one method and one attribute for these objects:

`NodeList.item(i)`

Return the *i*'th item from the sequence, if there is one, or `None`. The index *i* is not allowed to be less than zero or greater than or equal to the length of the sequence.

`NodeList.length`

The number of nodes in the sequence.

In addition, the Python DOM interface requires that some additional support is provided to allow `NodeList` objects to be used as Python sequences. All `NodeList` implementations must include support for `__len__()` and `__getitem__()`; this allows iteration over the `NodeList` in `for` statements and proper support for the `len()` built-in function.

If a DOM implementation supports modification of the document, the `NodeList` implementation must also support the `__setitem__()` and `__delitem__()` methods.

### DocumentType Objects

Information about the notations and entities declared by a document (including the external subset if the parser uses it and can provide the information) is available from a `DocumentType` object. The `DocumentType` for a document is available from the `Document` object's `doctype` attribute; if there is no `DOCTYPE` declaration for the document, the document's `doctype` attribute will be set to `None` instead of an instance of this interface.

`DocumentType` is a specialization of `Node`, and adds the following attributes:

`DocumentType.publicId`

The public identifier for the external subset of the document type definition. This will be a string or `None`.

`DocumentType.systemId`

The system identifier for the external subset of the document type definition. This will be a URI as a string, or `None`.

**DocumentType.internalSubset**

A string giving the complete internal subset from the document. This does not include the brackets which enclose the subset. If the document has no internal subset, this should be `None`.

**DocumentType.name**

The name of the root element as given in the `DOCTYPE` declaration, if present.

**DocumentType.entities**

This is a `NamedNodeMap` giving the definitions of external entities. For entity names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be `None` if the information is not provided by the parser, or if no entities are defined.

**DocumentType.notations**

This is a `NamedNodeMap` giving the definitions of notations. For notation names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be `None` if the information is not provided by the parser, or if no notations are defined.

## Document Objects

A `Document` represents an entire XML document, including its constituent elements, attributes, processing instructions, comments etc. Remember that it inherits properties from `Node`.

**Document.documentElement**

The one and only root element of the document.

**Document.createElement** (*tagName*)

Create and return a new element node. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as `insertBefore()` or `appendChild()`.

**Document.createElementNS** (*namespaceURI*, *tagName*)

Create and return a new element with a namespace. The *tagName* may have a prefix. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as `insertBefore()` or `appendChild()`.

**Document.createTextNode** (*data*)

Create and return a text node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

**Document.createComment** (*data*)

Create and return a comment node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

**Document.createProcessingInstruction** (*target*, *data*)

Create and return a processing instruction node containing the *target* and *data* passed as parameters. As with the other creation methods, this one does not insert the node into the tree.

**Document.createAttribute** (*name*)

Create and return an attribute node. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use the newly created attribute instance.

**Document.createAttributeNS** (*namespaceURI*, *qualifiedName*)

Create and return an attribute node with a namespace. The *tagName* may have a prefix. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use the newly created attribute instance.

**Document.getElementsByTagName** (*tagName*)

Search for all descendants (direct children, children's children, etc.) with a particular element type name.

`Document.getElementsByTagNameNS` (*namespaceURI*, *localName*)  
Search for all descendants (direct children, children's children, etc.) with a particular namespace URI and localname. The localname is the part of the namespace after the prefix.

## Element Objects

Element is a subclass of Node, so inherits all the attributes of that class.

`Element.tagName`  
The element type name. In a namespace-using document it may have colons in it. The value is a string.

`Element.getElementsByTagName` (*tagName*)  
Same as equivalent method in the Document class.

`Element.getElementsByTagNameNS` (*namespaceURI*, *localName*)  
Same as equivalent method in the Document class.

`Element.hasAttribute` (*name*)  
Returns true if the element has an attribute named by *name*.

`Element.hasAttributeNS` (*namespaceURI*, *localName*)  
Returns true if the element has an attribute named by *namespaceURI* and *localName*.

`Element.getAttribute` (*name*)  
Return the value of the attribute named by *name* as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

`Element.getAttributeNode` (*attrname*)  
Return the `Attr` node for the attribute named by *attrname*.

`Element.getAttributeNS` (*namespaceURI*, *localName*)  
Return the value of the attribute named by *namespaceURI* and *localName* as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

`Element.getAttributeNodeNS` (*namespaceURI*, *localName*)  
Return an attribute value as a node, given a *namespaceURI* and *localName*.

`Element.removeAttribute` (*name*)  
Remove an attribute by name. If there is no matching attribute, a `NotFoundError` is raised.

`Element.removeAttributeNode` (*oldAttr*)  
Remove and return *oldAttr* from the attribute list, if present. If *oldAttr* is not present, `NotFoundError` is raised.

`Element.removeAttributeNS` (*namespaceURI*, *localName*)  
Remove an attribute by name. Note that it uses a *localName*, not a *qname*. No exception is raised if there is no matching attribute.

`Element.setAttribute` (*name*, *value*)  
Set an attribute value from a string.

`Element.setAttributeNode` (*newAttr*)  
Add a new attribute node to the element, replacing an existing attribute if necessary if the *name* attribute matches. If a replacement occurs, the old attribute node will be returned. If *newAttr* is already in use, `InuseAttributeErr` will be raised.

`Element.setAttributeNodeNS` (*newAttr*)  
Add a new attribute node to the element, replacing an existing attribute if necessary if the *namespaceURI* and *localName* attributes match. If a replacement occurs, the old attribute node will be returned. If *newAttr* is already in use, `InuseAttributeErr` will be raised.

`Element.setAttributeNS(namespaceURI, qname, value)`

Set an attribute value from a string, given a *namespaceURI* and a *qname*. Note that a *qname* is the whole attribute name. This is different than above.

## Attr Objects

`Attr` inherits from `Node`, so inherits all its attributes.

`Attr.name`

The attribute name. In a namespace-using document it may include a colon.

`Attr.localName`

The part of the name following the colon if there is one, else the entire name. This is a read-only attribute.

`Attr.prefix`

The part of the name preceding the colon if there is one, else the empty string.

`Attr.value`

The text value of the attribute. This is a synonym for the `nodeValue` attribute.

## NamedNodeMap Objects

`NamedNodeMap` does *not* inherit from `Node`.

`NamedNodeMap.length`

The length of the attribute list.

`NamedNodeMap.item(index)`

Return an attribute with a particular index. The order you get the attributes in is arbitrary but will be consistent for the life of a DOM. Each item is an attribute node. Get its value with the `value` attribute.

There are also experimental methods that give this class more mapping behavior. You can use them or you can use the standardized `getAttribute*()` family of methods on the `Element` objects.

## Comment Objects

`Comment` represents a comment in the XML document. It is a subclass of `Node`, but cannot have child nodes.

`Comment.data`

The content of the comment as a string. The attribute contains all characters between the leading `<!--` and trailing `-->`, but does not include them.

## Text and CDATASection Objects

The `Text` interface represents text in the XML document. If the parser and DOM implementation support the DOM's XML extension, portions of the text enclosed in CDATA marked sections are stored in `CDATASection` objects. These two interfaces are identical, but provide different values for the `nodeType` attribute.

These interfaces extend the `Node` interface. They cannot have child nodes.

`Text.data`

The content of the text node as a string.

---

**Note:** The use of a `CDATASection` node does not indicate that the node represents a complete CDATA marked section, only that the content of the node was part of a CDATA section. A single CDATA section may be represented

by more than one node in the document tree. There is no way to determine whether two adjacent `CDATASection` nodes represent different CDATA marked sections.

---

### ProcessingInstruction Objects

Represents a processing instruction in the XML document; this inherits from the `Node` interface and cannot have child nodes.

`ProcessingInstruction.target`

The content of the processing instruction up to the first whitespace character. This is a read-only attribute.

`ProcessingInstruction.data`

The content of the processing instruction following the first whitespace character.

### Exceptions

New in version 2.1. The DOM Level 2 recommendation defines a single exception, `DOMException`, and a number of constants that allow applications to determine what sort of error occurred. `DOMException` instances carry a `code` attribute that provides the appropriate value for the specific exception.

The Python DOM interface provides the constants, but also expands the set of exceptions so that a specific exception exists for each of the exception codes defined by the DOM. The implementations must raise the appropriate specific exception, each of which carries the appropriate value for the `code` attribute.

**exception** `xml.dom.DOMException`

Base exception class used for all specific DOM exceptions. This exception class cannot be directly instantiated.

**exception** `xml.dom.DomstringSizeErr`

Raised when a specified range of text does not fit into a string. This is not known to be used in the Python DOM implementations, but may be received from DOM implementations not written in Python.

**exception** `xml.dom.HierarchyRequestErr`

Raised when an attempt is made to insert a node where the node type is not allowed.

**exception** `xml.dom.IndexSizeErr`

Raised when an index or size parameter to a method is negative or exceeds the allowed values.

**exception** `xml.dom.InuseAttributeErr`

Raised when an attempt is made to insert an `Attr` node that is already present elsewhere in the document.

**exception** `xml.dom.InvalidAccessErr`

Raised if a parameter or an operation is not supported on the underlying object.

**exception** `xml.dom.InvalidCharacterErr`

This exception is raised when a string parameter contains a character that is not permitted in the context it's being used in by the XML 1.0 recommendation. For example, attempting to create an `Element` node with a space in the element type name will cause this error to be raised.

**exception** `xml.dom.InvalidModificationErr`

Raised when an attempt is made to modify the type of a node.

**exception** `xml.dom.InvalidStateErr`

Raised when an attempt is made to use an object that is not defined or is no longer usable.

**exception** `xml.dom.NamespaceErr`

If an attempt is made to change any object in a way that is not permitted with regard to the [Namespaces in XML](#) recommendation, this exception is raised.

**exception `xml.dom.NotFoundErr`**

Exception when a node does not exist in the referenced context. For example, `NamedNodeMap.removeNamedItem()` will raise this if the node passed in does not exist in the map.

**exception `xml.dom.NotSupportedErr`**

Raised when the implementation does not support the requested type of object or operation.

**exception `xml.dom.NoDataAllowedErr`**

This is raised if data is specified for a node which does not support data.

**exception `xml.dom.NoModificationAllowedErr`**

Raised on attempts to modify an object where modifications are not allowed (such as for read-only nodes).

**exception `xml.dom.SyntaxErr`**

Raised when an invalid or illegal string is specified.

**exception `xml.dom.WrongDocumentErr`**

Raised when a node is inserted in a different document than it currently belongs to, and the implementation does not support migrating the node from one document to the other.

The exception codes defined in the DOM recommendation map to the exceptions described above according to this table:

Constant	Exception
DOMSTRING_SIZE_ERR	<code>DomstringSizeErr</code>
HIERARCHY_REQUEST_ERR	<code>HierarchyRequestErr</code>
INDEX_SIZE_ERR	<code>IndexSizeErr</code>
INUSE_ATTRIBUTE_ERR	<code>InuseAttributeErr</code>
INVALID_ACCESS_ERR	<code>InvalidAccessErr</code>
INVALID_CHARACTER_ERR	<code>InvalidCharacterErr</code>
INVALID_MODIFICATION_ERR	<code>InvalidModificationErr</code>
INVALID_STATE_ERR	<code>InvalidStateErr</code>
NAMESPACE_ERR	<code>NamespaceErr</code>
NOT_FOUND_ERR	<code>NotFoundErr</code>
NOT_SUPPORTED_ERR	<code>NotSupportedErr</code>
NO_DATA_ALLOWED_ERR	<code>NoDataAllowedErr</code>
NO_MODIFICATION_ALLOWED_ERR	<code>NoModificationAllowedErr</code>
SYNTAX_ERR	<code>SyntaxErr</code>
WRONG_DOCUMENT_ERR	<code>WrongDocumentErr</code>

## 19.6.3 Conformance

This section describes the conformance requirements and relationships between the Python DOM API, the W3C DOM recommendations, and the OMG IDL mapping for Python.

### Type Mapping

The primitive IDL types used in the DOM specification are mapped to Python types according to the following table.

IDL Type	Python Type
<code>boolean</code>	<code>IntegerType</code> (with a value of 0 or 1)
<code>int</code>	<code>IntegerType</code>
<code>long int</code>	<code>IntegerType</code>
<code>unsigned int</code>	<code>IntegerType</code>

Additionally, the `DOMString` defined in the recommendation is mapped to a Python string or Unicode string. Applications should be able to handle Unicode whenever a string is returned from the DOM.

The IDL `null` value is mapped to `None`, which may be accepted or provided by the implementation whenever `null` is allowed by the API.

### Accessor Methods

The mapping from OMG IDL to Python defines accessor functions for IDL attribute declarations in much the way the Java mapping does. Mapping the IDL declarations

```
readonly attribute string someValue;  
    attribute string anotherValue;
```

yields three accessor functions: a “get” method for `someValue` (`_get_someValue()`), and “get” and “set” methods for `anotherValue` (`_get_anotherValue()` and `_set_anotherValue()`). The mapping, in particular, does not require that the IDL attributes are accessible as normal Python attributes: `object.someValue` is *not* required to work, and may raise an `AttributeError`.

The Python DOM API, however, *does* require that normal attribute access work. This means that the typical surrogates generated by Python IDL compilers are not likely to work, and wrapper objects may be needed on the client if the DOM objects are accessed via CORBA. While this does require some additional consideration for CORBA DOM clients, the implementers with experience using DOM over CORBA from Python do not consider this a problem. Attributes that are declared `readonly` may not restrict write access in all DOM implementations.

In the Python DOM API, accessor functions are not required. If provided, they should take the form defined by the Python IDL mapping, but these methods are considered unnecessary since the attributes are accessible directly from Python. “Set” accessors should never be provided for `readonly` attributes.

The IDL definitions do not fully embody the requirements of the W3C DOM API, such as the notion of certain objects, such as the return value of `getElementsByTagName()`, being “live”. The Python DOM API does not require implementations to enforce such requirements.

## 19.7 `xml.dom.minidom` — Lightweight DOM implementation

New in version 2.0. **Source code:** [Lib/xml/dom/minidom.py](#)

---

`xml.dom.minidom` is a light-weight implementation of the Document Object Model interface. It is intended to be simpler than the full DOM and also significantly smaller.

---

**Note:** The `xml.dom.minidom` module provides an implementation of the W3C-DOM, with an API similar to that in other programming languages. Users who are unfamiliar with the W3C-DOM interface or who would like to write less code for processing XML files should consider using the `xml.etree.ElementTree` module instead.

---

DOM applications typically start by parsing some XML into a DOM. With `xml.dom.minidom`, this is done through the parse functions:

```
from xml.dom.minidom import parse, parseString  
  
dom1 = parse('c:\\temp\\mydata.xml') # parse an XML file by name  
  
datasource = open('c:\\temp\\mydata.xml')  
dom2 = parse(datasource) # parse an open file
```

```
dom3 = parseString('<myxml>Some data<empty/> some more data</myxml>')
```

The `parse()` function can take either a filename or an open file object.

```
xml.dom.minidom.parse(filename_or_file[, parser[, bufsize]])
```

Return a `Document` from the given input. `filename_or_file` may be either a file name, or a file-like object. `parser`, if given, must be a SAX2 parser object. This function will change the document handler of the parser and activate namespace support; other parser configuration (like setting an entity resolver) must have been done in advance.

If you have XML in a string, you can use the `parseString()` function instead:

```
xml.dom.minidom.parseString(string[, parser])
```

Return a `Document` that represents the `string`. This method creates a `StringIO` object for the string and passes that on to `parse()`.

Both functions return a `Document` object representing the content of the document.

What the `parse()` and `parseString()` functions do is connect an XML parser with a “DOM builder” that can accept parse events from any SAX parser and convert them into a DOM tree. The name of the functions are perhaps misleading, but are easy to grasp when learning the interfaces. The parsing of the document will be completed before these functions return; it’s simply that these functions do not provide a parser implementation themselves.

You can also create a `Document` by calling a method on a “DOM Implementation” object. You can get this object either by calling the `getDOMImplementation()` function in the `xml.dom` package or the `xml.dom.minidom` module. Using the implementation from the `xml.dom.minidom` module will always return a `Document` instance from the minidom implementation, while the version from `xml.dom` may provide an alternate implementation (this is likely if you have the `PyXML` package installed). Once you have a `Document`, you can add child nodes to it to populate the DOM:

```
from xml.dom.minidom import getDOMImplementation

impl = getDOMImplementation()

newdoc = impl.createDocument(None, "some_tag", None)
top_element = newdoc.documentElement
text = newdoc.createTextNode('Some textual content.')
top_element.appendChild(text)
```

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification. The main property of the document object is the `documentElement` property. It gives you the main element in the XML document: the one that holds all others. Here is an example program:

```
dom3 = parseString("<myxml>Some data</myxml>")
assert dom3.documentElement.tagName == "myxml"
```

When you are finished with a DOM tree, you may optionally call the `unlink()` method to encourage early cleanup of the now-unneeded objects. `unlink()` is a `xml.dom.minidom`-specific extension to the DOM API that renders the node and its descendants are essentially useless. Otherwise, Python’s garbage collector will eventually take care of the objects in the tree.

**See Also:**

**Document Object Model (DOM) Level 1 Specification** The W3C recommendation for the DOM supported by `xml.dom.minidom`.

## 19.7.1 DOM Objects

The definition of the DOM API for Python is given as part of the `xml.dom` module documentation. This section lists the differences between the API and `xml.dom.minidom`.

`Node.unlink()`

Break internal references within the DOM so that it will be garbage collected on versions of Python without cyclic GC. Even when cyclic GC is available, using this can make large amounts of memory available sooner, so calling this on DOM objects as soon as they are no longer needed is good practice. This only needs to be called on the `Document` object, but may be called on child nodes to discard children of that node.

`Node.writexml(writer, indent="" , addindent="" , newl="" )`

Write XML to the writer object. The writer should have a `write()` method which matches that of the file object interface. The `indent` parameter is the indentation of the current node. The `addindent` parameter is the incremental indentation to use for subnodes of the current one. The `newl` parameter specifies the string to use to terminate newlines.

For the `Document` node, an additional keyword argument `encoding` can be used to specify the encoding field of the XML header. Changed in version 2.1: The optional keyword parameters `indent`, `addindent`, and `newl` were added to support pretty output. Changed in version 2.3: For the `Document` node, an additional keyword argument `encoding` can be used to specify the encoding field of the XML header.

`Node.toxml([encoding])`

Return the XML that the DOM represents as a string.

With no argument, the XML header does not specify an encoding, and the result is Unicode string if the default encoding cannot represent all characters in the document. Encoding this string in an encoding other than UTF-8 is likely incorrect, since UTF-8 is the default encoding of XML.

With an explicit `encoding`<sup>2</sup> argument, the result is a byte string in the specified encoding. It is recommended that this argument is always specified. To avoid `UnicodeError` exceptions in case of unrepresentable text data, the encoding argument should be specified as “utf-8”. Changed in version 2.3: the `encoding` argument was introduced; see `writexml()`.

`Node.toprettyxml([indent="" [, newl="" [, encoding="" ]]])`

Return a pretty-printed version of the document. `indent` specifies the indentation string and defaults to a tabulator; `newl` specifies the string emitted at the end of each line and defaults to `\n`. New in version 2.1. Changed in version 2.3: the encoding argument was introduced; see `writexml()`.

The following standard DOM methods have special considerations with `xml.dom.minidom`:

`Node.cloneNode(deep)`

Although this method was present in the version of `xml.dom.minidom` packaged with Python 2.0, it was seriously broken. This has been corrected for subsequent releases.

## 19.7.2 DOM Example

This example program is a fairly realistic example of a simple program. In this particular case, we do not take much advantage of the flexibility of the DOM.

```
import xml.dom.minidom
```

```
document = """\
<slideshow>
<title>Demo slideshow</title>
<slide><title>Slide title</title>
```

<sup>2</sup> The encoding string included in XML output should conform to the appropriate standards. For example, “UTF-8” is valid, but “UTF8” is not. See <http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl> and <http://www.iana.org/assignments/character-sets>.

```

<point>This is a demo</point>
<point>Of a program for processing slides</point>
</slide>

<slide><title>Another demo slide</title>
<point>It is important</point>
<point>To have more than</point>
<point>one slide</point>
</slide>
</slideshow>
"""

dom = xml.dom.minidom.parseString(document)

def getText(nodelist):
    rc = []
    for node in nodelist:
        if node.nodeType == node.TEXT_NODE:
            rc.append(node.data)
    return ' '.join(rc)

def handleSlideshow(slideshow):
    print "<html>"
    handleSlideshowTitle(slideshow.getElementsByTagName("title")[0])
    slides = slideshow.getElementsByTagName("slide")
    handleToc(slides)
    handleSlides(slides)
    print "</html>"

def handleSlides(slides):
    for slide in slides:
        handleSlide(slide)

def handleSlide(slide):
    handleSlideTitle(slide.getElementsByTagName("title")[0])
    handlePoints(slide.getElementsByTagName("point"))

def handleSlideshowTitle(title):
    print "<title>%s</title>" % getText(title.childNodes)

def handleSlideTitle(title):
    print "<h2>%s</h2>" % getText(title.childNodes)

def handlePoints(points):
    print "<ul>"
    for point in points:
        handlePoint(point)
    print "</ul>"

def handlePoint(point):
    print "<li>%s</li>" % getText(point.childNodes)

def handleToc(slides):
    for slide in slides:

```

```
title = slide.getElementsByTagName("title")[0]
print "<p>%s</p>" % getText(title.childNodes)
```

```
handleSlideshow(dom)
```

### 19.7.3 minidom and the DOM standard

The `xml.dom.minidom` module is essentially a DOM 1.0-compatible DOM with some DOM 2 features (primarily namespace features).

Usage of the DOM interface in Python is straight-forward. The following mapping rules apply:

- Interfaces are accessed through instance objects. Applications should not instantiate the classes themselves; they should use the creator functions available on the `Document` object. Derived interfaces support all operations (and attributes) from the base interfaces, plus any new operations.
- Operations are used as methods. Since the DOM uses only `in` parameters, the arguments are passed in normal order (from left to right). There are no optional arguments. `void` operations return `None`.
- IDL attributes map to instance attributes. For compatibility with the OMG IDL language mapping for Python, an attribute `foo` can also be accessed through accessor methods `_get_foo()` and `_set_foo()`. `readonly` attributes must not be changed; this is not enforced at runtime.
- The types `short int`, `unsigned int`, `unsigned long long`, and `boolean` all map to Python integer objects.
- The type `DOMString` maps to Python strings. `xml.dom.minidom` supports either byte or Unicode strings, but will normally produce Unicode strings. Values of type `DOMString` may also be `None` where allowed to have the IDL `null` value by the DOM specification from the W3C.
- `const` declarations map to variables in their respective scope (e.g. `xml.dom.minidom.Node.PROCESSING_INSTRUCTION_NODE`); they must not be changed.
- `DOMException` is currently not supported in `xml.dom.minidom`. Instead, `xml.dom.minidom` uses standard Python exceptions such as `TypeError` and `AttributeError`.
- `NodeList` objects are implemented using Python's built-in list type. Starting with Python 2.2, these objects provide the interface defined in the DOM specification, but with earlier versions of Python they do not support the official API. They are, however, much more "Pythonic" than the interface defined in the W3C recommendations.

The following interfaces have no implementation in `xml.dom.minidom`:

- `DOMTimeStamp`
- `DocumentType` (added in Python 2.1)
- `DOMImplementation` (added in Python 2.1)
- `CharacterData`
- `CDATASection`
- `Notation`
- `Entity`
- `EntityReference`
- `DocumentFragment`

Most of these reflect information in the XML document that is not of general utility to most DOM users.

## 19.8 `xml.dom.pulldom` — Support for building partial DOM trees

New in version 2.0. **Source code:** [Lib/xml/dom/pulldom.py](#)

`xml.dom.pulldom` allows building only selected portions of a Document Object Model representation of a document from SAX events.

```
class xml.dom.pulldom.PullDOM([documentFactory])
    xml.sax.handler.ContentHandler implementation that ...
```

```
class xml.dom.pulldom.DOMEventStream(stream, parser, bufsize)
    ...
```

```
class xml.dom.pulldom.SAX2DOM([documentFactory])
    xml.sax.handler.ContentHandler implementation that ...
```

```
xml.dom.pulldom.parse(stream_or_string[, parser[, bufsize ]])
```

```
...
xml.dom.pulldom.parseString(string[, parser ])
```

```
...
xml.dom.pulldom.default_bufsize
    Default value for the bufsize parameter to parse(). Changed in version 2.1: The value of this variable can be changed before calling parse() and the new value will take effect.
```

### 19.8.1 `DOMEventStream` Objects

```
DOMEventStream.getEvent()
```

```
...
DOMEventStream.expandNode(node)
```

```
...
DOMEventStream.reset()
...
```

## 19.9 `xml.sax` — Support for SAX2 parsers

New in version 2.0. The `xml.sax` package provides a number of modules which implement the Simple API for XML (SAX) interface for Python. The package itself provides the SAX exceptions and the convenience functions which will be most used by users of the SAX API.

The convenience functions are:

```
xml.sax.make_parser([parser_list])
```

Create and return a SAX `XMLReader` object. The first parser found will be used. If *parser\_list* is provided, it must be a sequence of strings which name modules that have a function named `create_parser()`. Modules listed in *parser\_list* will be used before modules in the default list of parsers.

```
xml.sax.parse(filename_or_stream, handler[, error_handler ])
```

Create a SAX parser and use it to parse a document. The document, passed in as *filename\_or\_stream*, can be a filename or a file object. The *handler* parameter needs to be a SAX `ContentHandler` instance. If *error\_handler* is given, it must be a SAX `ErrorHandler` instance; if omitted, `SAXParseException` will be raised on all errors. There is no return value; all work must be done by the *handler* passed in.

`xml.sax.parseString` (*string*, *handler* [, *error\_handler* ])

Similar to `parse()`, but parses from a buffer *string* received as a parameter.

A typical SAX application uses three kinds of objects: readers, handlers and input sources. “Reader” in this context is another term for parser, i.e. some piece of code that reads the bytes or characters from the input source, and produces a sequence of events. The events then get distributed to the handler objects, i.e. the reader invokes a method on the handler. A SAX application must therefore obtain a reader object, create or open the input sources, create the handlers, and connect these objects all together. As the final step of preparation, the reader is called to parse the input. During parsing, methods on the handler objects are called based on structural and syntactic events from the input data.

For these objects, only the interfaces are relevant; they are normally not instantiated by the application itself. Since Python does not have an explicit notion of interface, they are formally introduced as classes, but applications may use implementations which do not inherit from the provided classes. The `InputSource`, `Locator`, `Attributes`, `AttributesNS`, and `XMLReader` interfaces are defined in the module `xml.sax.xmlreader`. The handler interfaces are defined in `xml.sax.handler`. For convenience, `InputSource` (which is often instantiated directly) and the handler classes are also available from `xml.sax`. These interfaces are described below.

In addition to these classes, `xml.sax` provides the following exception classes.

**exception** `xml.sax.SAXException` (*msg* [, *exception* ])

Encapsulate an XML error or warning. This class can contain basic error or warning information from either the XML parser or the application: it can be subclassed to provide additional functionality or to add localization. Note that although the handlers defined in the `ErrorHandler` interface receive instances of this exception, it is not required to actually raise the exception — it is also useful as a container for information.

When instantiated, *msg* should be a human-readable description of the error. The optional *exception* parameter, if given, should be `None` or an exception that was caught by the parsing code and is being passed along as information.

This is the base class for the other SAX exception classes.

**exception** `xml.sax.SAXParseException` (*msg*, *exception*, *locator*)

Subclass of `SAXException` raised on parse errors. Instances of this class are passed to the methods of the SAX `ErrorHandler` interface to provide information about the parse error. This class supports the SAX `Locator` interface as well as the `SAXException` interface.

**exception** `xml.sax.SAXNotRecognizedException` (*msg* [, *exception* ])

Subclass of `SAXException` raised when a SAX `XMLReader` is confronted with an unrecognized feature or property. SAX applications and extensions may use this class for similar purposes.

**exception** `xml.sax.SAXNotSupportedException` (*msg* [, *exception* ])

Subclass of `SAXException` raised when a SAX `XMLReader` is asked to enable a feature that is not supported, or to set a property to a value that the implementation does not support. SAX applications and extensions may use this class for similar purposes.

**See Also:**

**SAX: The Simple API for XML** This site is the focal point for the definition of the SAX API. It provides a Java implementation and online documentation. Links to implementations and historical information are also available.

**Module** `xml.sax.handler` Definitions of the interfaces for application-provided objects.

**Module** `xml.sax.saxutils` Convenience functions for use in SAX applications.

**Module** `xml.sax.xmlreader` Definitions of the interfaces for parser-provided objects.

## 19.9.1 SAXException Objects

The `SAXException` exception class supports the following methods:

`SAXException.getMessage()`

Return a human-readable message describing the error condition.

`SAXException.getException()`

Return an encapsulated exception object, or `None`.

## 19.10 `xml.sax.handler` — Base classes for SAX handlers

New in version 2.0. The SAX API defines four kinds of handlers: content handlers, DTD handlers, error handlers, and entity resolvers. Applications normally only need to implement those interfaces whose events they are interested in; they can implement the interfaces in a single object or in multiple objects. Handler implementations should inherit from the base classes provided in the module `xml.sax.handler`, so that all methods get default implementations.

**class** `xml.sax.handler.ContentHandler`

This is the main callback interface in SAX, and the one most important to applications. The order of events in this interface mirrors the order of the information in the document.

**class** `xml.sax.handler.DTDHandler`

Handle DTD events.

This interface specifies only those DTD events required for basic parsing (unparsed entities and attributes).

**class** `xml.sax.handler.EntityResolver`

Basic interface for resolving entities. If you create an object implementing this interface, then register the object with your Parser, the parser will call the method in your object to resolve all external entities.

**class** `xml.sax.handler.ErrorHandler`

Interface used by the parser to present error and warning messages to the application. The methods of this object control whether errors are immediately converted to exceptions or are handled in some other way.

In addition to these classes, `xml.sax.handler` provides symbolic constants for the feature and property names.

`xml.sax.handler.feature_namespaces`

value: `"http://xml.org/sax/features/namespaces"`

true: Perform Namespace processing.

false: Optionally do not perform Namespace processing (implies namespace-prefixes; default).

access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.feature_namespace_prefixes`

value: `"http://xml.org/sax/features/namespace-prefixes"`

true: Report the original prefixed names and attributes used for Namespace declarations.

false: Do not report attributes used for Namespace declarations, and optionally do not report original prefixed names (default).

access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.feature_string_interning`

value: `"http://xml.org/sax/features/string-interning"`

true: All element names, prefixes, attribute names, Namespace URIs, and local names are interned using the built-in intern function.

false: Names are not necessarily interned, although they may be (default).

access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.feature_validation`

value: "http://xml.org/sax/features/validation"  
true: Report all validation errors (implies external-general-entities and external-parameter-entities).  
false: Do not report validation errors.  
access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.feature_external_ges`

value: "http://xml.org/sax/features/external-general-entities"  
true: Include all external general (text) entities.  
false: Do not include external general entities.  
access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.feature_external_pes`

value: "http://xml.org/sax/features/external-parameter-entities"  
true: Include all external parameter entities, including the external DTD subset.  
false: Do not include any external parameter entities, even the external DTD subset.  
access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.all_features`

List of all features.

`xml.sax.handler.property_lexical_handler`

value: "http://xml.org/sax/properties/lexical-handler"  
data type: `xml.sax.sax2lib.LexicalHandler` (not supported in Python 2)  
description: An optional extension handler for lexical events like comments.  
access: read/write

`xml.sax.handler.property_declaration_handler`

value: "http://xml.org/sax/properties/declaration-handler"  
data type: `xml.sax.sax2lib.DeclHandler` (not supported in Python 2)  
description: An optional extension handler for DTD-related events other than notations and unparsed entities.  
access: read/write

`xml.sax.handler.property_dom_node`

value: "http://xml.org/sax/properties/dom-node"  
data type: `org.w3c.dom.Node` (not supported in Python 2)  
description: When parsing, the current DOM node being visited if this is a DOM iterator; when not parsing, the root DOM node for iteration.  
access: (parsing) read-only; (not parsing) read/write

`xml.sax.handler.property_xml_string`

value: "http://xml.org/sax/properties/xml-string"  
data type: String  
description: The literal string of characters that was the source for the current event.

access: read-only

`xml.sax.handler.all_properties`

List of all known property names.

## 19.10.1 ContentHandler Objects

Users are expected to subclass `ContentHandler` to support their application. The following methods are called by the parser on the appropriate events in the input document:

`ContentHandler.setDocumentLocator` (*locator*)

Called by the parser to give the application a locator for locating the origin of document events.

SAX parsers are strongly encouraged (though not absolutely required) to supply a locator: if it does so, it must supply the locator to the application by invoking this method before invoking any of the other methods in the `DocumentHandler` interface.

The locator allows the application to determine the end position of any document-related event, even if the parser is not reporting an error. Typically, the application will use this information for reporting its own errors (such as character content that does not match an application's business rules). The information returned by the locator is probably not sufficient for use with a search engine.

Note that the locator will return correct information only during the invocation of the events in this interface. The application should not attempt to use it at any other time.

`ContentHandler.startDocument` ()

Receive notification of the beginning of a document.

The SAX parser will invoke this method only once, before any other methods in this interface or in `DTDHandler` (except for `setDocumentLocator`()).

`ContentHandler.endDocument` ()

Receive notification of the end of a document.

The SAX parser will invoke this method only once, and it will be the last method invoked during the parse. The parser shall not invoke this method until it has either abandoned parsing (because of an unrecoverable error) or reached the end of input.

`ContentHandler.startPrefixMapping` (*prefix, uri*)

Begin the scope of a prefix-URI Namespace mapping.

The information from this event is not necessary for normal Namespace processing: the SAX XML reader will automatically replace prefixes for element and attribute names when the `feature_namespaces` feature is enabled (the default).

There are cases, however, when applications need to use prefixes in character data or in attribute values, where they cannot safely be expanded automatically; the `startPrefixMapping()` and `endPrefixMapping()` events supply the information to the application to expand prefixes in those contexts itself, if necessary.

Note that `startPrefixMapping()` and `endPrefixMapping()` events are not guaranteed to be properly nested relative to each-other: all `startPrefixMapping()` events will occur before the corresponding `startElement()` event, and all `endPrefixMapping()` events will occur after the corresponding `endElement()` event, but their order is not guaranteed.

`ContentHandler.endPrefixMapping` (*prefix*)

End the scope of a prefix-URI mapping.

See `startPrefixMapping()` for details. This event will always occur after the corresponding `endElement()` event, but the order of `endPrefixMapping()` events is not otherwise guaranteed.

`ContentHandler.startElement` (*name*, *attrs*)

Signals the start of an element in non-namespace mode.

The *name* parameter contains the raw XML 1.0 name of the element type as a string and the *attrs* parameter holds an object of the `Attributes` interface (see *The Attributes Interface*) containing the attributes of the element. The object passed as *attrs* may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the attributes, use the `copy()` method of the *attrs* object.

`ContentHandler.endElement` (*name*)

Signals the end of an element in non-namespace mode.

The *name* parameter contains the name of the element type, just as with the `startElement()` event.

`ContentHandler.startElementNS` (*name*, *qname*, *attrs*)

Signals the start of an element in namespace mode.

The *name* parameter contains the name of the element type as a (*uri*, *localname*) tuple, the *qname* parameter contains the raw XML 1.0 name used in the source document, and the *attrs* parameter holds an instance of the `AttributesNS` interface (see *The AttributesNS Interface*) containing the attributes of the element. If no namespace is associated with the element, the *uri* component of *name* will be `None`. The object passed as *attrs* may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the attributes, use the `copy()` method of the *attrs* object.

Parsers may set the *qname* parameter to `None`, unless the `feature_namespace_prefixes` feature is activated.

`ContentHandler.endElementNS` (*name*, *qname*)

Signals the end of an element in namespace mode.

The *name* parameter contains the name of the element type, just as with the `startElementNS()` method, likewise the *qname* parameter.

`ContentHandler.characters` (*content*)

Receive notification of character data.

The Parser will call this method to report each chunk of character data. SAX parsers may return all contiguous character data in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity so that the Locator provides useful information.

*content* may be a Unicode string or a byte string; the `expat` reader module produces always Unicode strings.

---

**Note:** The earlier SAX 1 interface provided by the Python XML Special Interest Group used a more Java-like interface for this method. Since most parsers used from Python did not take advantage of the older interface, the simpler signature was chosen to replace it. To convert old code to the new interface, use *content* instead of slicing *content* with the old *offset* and *length* parameters.

---

`ContentHandler.ignorableWhitespace` (*whitespace*)

Receive notification of ignorable whitespace in element content.

Validating Parsers must use this method to report each chunk of ignorable whitespace (see the W3C XML 1.0 recommendation, section 2.10): non-validating parsers may also use this method if they are capable of parsing and using content models.

SAX parsers may return all contiguous whitespace in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity, so that the Locator provides useful information.

`ContentHandler.processingInstruction` (*target*, *data*)

Receive notification of a processing instruction.

The Parser will invoke this method once for each processing instruction found: note that processing instructions may occur before or after the main document element.

A SAX parser should never report an XML declaration (XML 1.0, section 2.8) or a text declaration (XML 1.0, section 4.3.1) using this method.

`ContentHandler`.**skippedEntity** (*name*)

Receive notification of a skipped entity.

The Parser will invoke this method once for each entity skipped. Non-validating processors may skip entities if they have not seen the declarations (because, for example, the entity was declared in an external DTD subset). All processors may skip external entities, depending on the values of the `feature_external_ges` and the `feature_external_pes` properties.

## 19.10.2 DTDHandler Objects

`DTDHandler` instances provide the following methods:

`DTDHandler`.**notationDecl** (*name*, *publicId*, *systemId*)

Handle a notation declaration event.

`DTDHandler`.**unparsedEntityDecl** (*name*, *publicId*, *systemId*, *ndata*)

Handle an unparsed entity declaration event.

## 19.10.3 EntityResolver Objects

`EntityResolver`.**resolveEntity** (*publicId*, *systemId*)

Resolve the system identifier of an entity and return either the system identifier to read from as a string, or an `InputSource` to read from. The default implementation returns *systemId*.

## 19.10.4 ErrorHandler Objects

Objects with this interface are used to receive error and warning information from the `XMLReader`. If you create an object that implements this interface, then register the object with your `XMLReader`, the parser will call the methods in your object to report all warnings and errors. There are three levels of errors available: warnings, (possibly) recoverable errors, and unrecoverable errors. All methods take a `SAXParseException` as the only parameter. Errors and warnings may be converted to an exception by raising the passed-in exception object.

`ErrorHandler`.**error** (*exception*)

Called when the parser encounters a recoverable error. If this method does not raise an exception, parsing may continue, but further document information should not be expected by the application. Allowing the parser to continue may allow additional errors to be discovered in the input document.

`ErrorHandler`.**fatalError** (*exception*)

Called when the parser encounters an error it cannot recover from; parsing is expected to terminate when this method returns.

`ErrorHandler`.**warning** (*exception*)

Called when the parser presents minor warning information to the application. Parsing is expected to continue when this method returns, and document information will continue to be passed to the application. Raising an exception in this method will cause parsing to end.

## 19.11 `xml.sax.saxutils` — SAX Utilities

New in version 2.0. The module `xml.sax.saxutils` contains a number of classes and functions that are commonly useful when creating SAX applications, either in direct use, or as base classes.

`xml.sax.saxutils.escape(data[, entities])`

Escape `'&'`, `'<'`, and `'>'` in a string of data.

You can escape other strings of data by passing a dictionary as the optional `entities` parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. The characters `'&'`, `'<'` and `'>'` are always escaped, even if `entities` is provided.

`xml.sax.saxutils.unescape(data[, entities])`

Unescape `'&amp;'`, `'&lt;'`, and `'&gt;'` in a string of data.

You can unescape other strings of data by passing a dictionary as the optional `entities` parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. `'&amp;'`, `'&lt;'`, and `'&gt;'` are always unescaped, even if `entities` is provided. New in version 2.3.

`xml.sax.saxutils.quoteattr(data[, entities])`

Similar to `escape()`, but also prepares `data` to be used as an attribute value. The return value is a quoted version of `data` with any additional required replacements. `quoteattr()` will select a quote character based on the content of `data`, attempting to avoid encoding any quote characters in the string. If both single- and double-quote characters are already in `data`, the double-quote characters will be encoded and `data` will be wrapped in double-quotes. The resulting string can be used directly as an attribute value:

```
>>> print "<element attr=%s>" % quoteattr("ab ' cd \" ef")
<element attr="ab ' cd &quot; ef">
```

This function is useful when generating attribute values for HTML or any SGML using the reference concrete syntax. New in version 2.2.

**class** `xml.sax.saxutils.XMLGenerator([out[, encoding]])`

This class implements the `ContentHandler` interface by writing SAX events back into an XML document. In other words, using an `XMLGenerator` as the content handler will reproduce the original document being parsed. `out` should be a file-like object which will default to `sys.stdout`. `encoding` is the encoding of the output stream which defaults to `'iso-8859-1'`.

**class** `xml.sax.saxutils.XMLFilterBase(base)`

This class is designed to sit between an `XMLReader` and the client application's event handlers. By default, it does nothing but pass requests up to the reader and events on to the handlers unmodified, but subclasses can override specific methods to modify the event stream or the configuration requests as they pass through.

`xml.sax.saxutils.prepare_input_source(source[, base])`

This function takes an input source and an optional base URL and returns a fully resolved `InputSource` object ready for reading. The input source can be given as a string, a file-like object, or an `InputSource` object; parsers will use this function to implement the polymorphic `source` argument to their `parse()` method.

## 19.12 `xml.sax.xmlreader` — Interface for XML parsers

New in version 2.0. SAX parsers implement the `XMLReader` interface. They are implemented in a Python module, which must provide a function `create_parser()`. This function is invoked by `xml.sax.make_parser()` with no arguments to create a new parser object.

**class** `xml.sax.xmlreader.XMLReader`

Base class which can be inherited by SAX parsers.

**class** `xml.sax.xmlreader.IncrementalParser`

In some cases, it is desirable not to parse an input source at once, but to feed chunks of the document as they get available. Note that the reader will normally not read the entire file, but read it in chunks as well; still `parse()` won't return until the entire document is processed. So these interfaces should be used if the blocking behaviour of `parse()` is not desirable.

When the parser is instantiated it is ready to begin accepting data from the feed method immediately. After parsing has been finished with a call to `close` the `reset` method must be called to make the parser ready to accept new data, either from `feed` or using the `parse` method.

Note that these methods must *not* be called during parsing, that is, after `parse` has been called and before it returns.

By default, the class also implements the `parse` method of the `XMLReader` interface using the `feed`, `close` and `reset` methods of the `IncrementalParser` interface as a convenience to SAX 2.0 driver writers.

**class** `xml.sax.xmlreader.Locator`

Interface for associating a SAX event with a document location. A locator object will return valid results only during calls to `DocumentHandler` methods; at any other time, the results are unpredictable. If information is not available, methods may return `None`.

**class** `xml.sax.xmlreader.InputSource` (`[systemId]`)

Encapsulation of the information needed by the `XMLReader` to read entities.

This class may include information about the public identifier, system identifier, byte stream (possibly with character encoding information) and/or the character stream of an entity.

Applications will create objects of this class for use in the `XMLReader.parse()` method and for returning from `EntityResolver.resolveEntity`.

An `InputSource` belongs to the application, the `XMLReader` is not allowed to modify `InputSource` objects passed to it from the application, although it may make copies and modify those.

**class** `xml.sax.xmlreader.AttributesImpl` (`attrs`)

This is an implementation of the `Attributes` interface (see section *The Attributes Interface*). This is a dictionary-like object which represents the element attributes in a `startElement()` call. In addition to the most useful dictionary operations, it supports a number of other methods as described by the interface. Objects of this class should be instantiated by readers; `attrs` must be a dictionary-like object containing a mapping from attribute names to attribute values.

**class** `xml.sax.xmlreader.AttributesNSImpl` (`attrs, qnames`)

Namespace-aware variant of `AttributesImpl`, which will be passed to `startElementNS()`. It is derived from `AttributesImpl`, but understands attribute names as two-tuples of `namespaceURI` and `localname`. In addition, it provides a number of methods expecting qualified names as they appear in the original document. This class implements the `AttributesNS` interface (see section *The AttributesNS Interface*).

## 19.12.1 XMLReader Objects

The `XMLReader` interface supports the following methods:

`XMLReader.parse` (`source`)

Process an input source, producing SAX events. The `source` object can be a system identifier (a string identifying the input source – typically a file name or an URL), a file-like object, or an `InputSource` object. When `parse()` returns, the input is completely processed, and the parser object can be discarded or reset. As a limitation, the current implementation only accepts byte streams; processing of character streams is for further study.

`XMLReader.getContentHandler` ()

Return the current `ContentHandler`.

`XMLReader.setContentHandler(handler)`

Set the current `ContentHandler`. If no `ContentHandler` is set, content events will be discarded.

`XMLReader.getDTDHandler()`

Return the current `DTDHandler`.

`XMLReader.setDTDHandler(handler)`

Set the current `DTDHandler`. If no `DTDHandler` is set, DTD events will be discarded.

`XMLReader.getEntityResolver()`

Return the current `EntityResolver`.

`XMLReader.setEntityResolver(handler)`

Set the current `EntityResolver`. If no `EntityResolver` is set, attempts to resolve an external entity will result in opening the system identifier for the entity, and fail if it is not available.

`XMLReader.getErrorHandler()`

Return the current `ErrorHandler`.

`XMLReader.setErrorHandler(handler)`

Set the current error handler. If no `ErrorHandler` is set, errors will be raised as exceptions, and warnings will be printed.

`XMLReader.setLocale(locale)`

Allow an application to set the locale for errors and warnings.

SAX parsers are not required to provide localization for errors and warnings; if they cannot support the requested locale, however, they must raise a SAX exception. Applications may request a locale change in the middle of a parse.

`XMLReader.getFeature(featurename)`

Return the current setting for feature *featurename*. If the feature is not recognized, `SAXNotRecognizedException` is raised. The well-known featurenames are listed in the module `xml.sax.handler`.

`XMLReader.setFeature(featurename, value)`

Set the *featurename* to *value*. If the feature is not recognized, `SAXNotRecognizedException` is raised. If the feature or its setting is not supported by the parser, `SAXNotSupportedException` is raised.

`XMLReader.getProperty(propertyname)`

Return the current setting for property *propertyname*. If the property is not recognized, a `SAXNotRecognizedException` is raised. The well-known propertynames are listed in the module `xml.sax.handler`.

`XMLReader.setProperty(propertyname, value)`

Set the *propertyname* to *value*. If the property is not recognized, `SAXNotRecognizedException` is raised. If the property or its setting is not supported by the parser, `SAXNotSupportedException` is raised.

### 19.12.2 IncrementalParser Objects

Instances of `IncrementalParser` offer the following additional methods:

`IncrementalParser.feed(data)`

Process a chunk of *data*.

`IncrementalParser.close()`

Assume the end of the document. That will check well-formedness conditions that can be checked only at the end, invoke handlers, and may clean up resources allocated during parsing.

`IncrementalParser.reset()`

This method is called after `close` has been called to reset the parser so that it is ready to parse new documents. The results of calling `parse` or `feed` after `close` without calling `reset` are undefined.

### 19.12.3 Locator Objects

Instances of `Locator` provide these methods:

`Locator.getColumnNumber()`

Return the column number where the current event ends.

`Locator.getLineNumber()`

Return the line number where the current event ends.

`Locator.getPublicId()`

Return the public identifier for the current event.

`Locator.getSystemId()`

Return the system identifier for the current event.

### 19.12.4 InputSource Objects

`InputSource.setPublicId(id)`

Sets the public identifier of this `InputSource`.

`InputSource.getPublicId()`

Returns the public identifier of this `InputSource`.

`InputSource.setSystemId(id)`

Sets the system identifier of this `InputSource`.

`InputSource.getSystemId()`

Returns the system identifier of this `InputSource`.

`InputSource.setEncoding(encoding)`

Sets the character encoding of this `InputSource`.

The encoding must be a string acceptable for an XML encoding declaration (see section 4.3.3 of the XML recommendation).

The encoding attribute of the `InputSource` is ignored if the `InputSource` also contains a character stream.

`InputSource.getEncoding()`

Get the character encoding of this `InputSource`.

`InputSource.setByteStream(bytefile)`

Set the byte stream (a Python file-like object which does not perform byte-to-character conversion) for this input source.

The SAX parser will ignore this if there is also a character stream specified, but it will use a byte stream in preference to opening a URI connection itself.

If the application knows the character encoding of the byte stream, it should set it with the `setEncoding` method.

`InputSource.getByteStream()`

Get the byte stream for this input source.

The `getEncoding` method will return the character encoding for this byte stream, or `None` if unknown.

`InputSource.setCharacterStream(charfile)`

Set the character stream for this input source. (The stream must be a Python 1.6 Unicode-wrapped file-like that performs conversion to Unicode strings.)

If there is a character stream specified, the SAX parser will ignore any byte stream and will not attempt to open a URI connection to the system identifier.

`InputSource.getCharacterStream()`

Get the character stream for this input source.

### 19.12.5 The `Attributes` Interface

`Attributes` objects implement a portion of the mapping protocol, including the methods `copy()`, `get()`, `has_key()`, `items()`, `keys()`, and `values()`. The following methods are also provided:

`Attributes.getLength()`

Return the number of attributes.

`Attributes.getNames()`

Return the names of the attributes.

`Attributes.getType(name)`

Returns the type of the attribute *name*, which is normally 'CDATA'.

`Attributes.getValue(name)`

Return the value of attribute *name*.

### 19.12.6 The `AttributesNS` Interface

This interface is a subtype of the `Attributes` interface (see section *The Attributes Interface*). All methods supported by that interface are also available on `AttributesNS` objects.

The following methods are also available:

`AttributesNS.getValueByQName(name)`

Return the value for a qualified name.

`AttributesNS.getNameByQName(name)`

Return the (namespace, localname) pair for a qualified *name*.

`AttributesNS.getQNameByName(name)`

Return the qualified name for a (namespace, localname) pair.

`AttributesNS.getQNames()`

Return the qualified names of all attributes.

## 19.13 `xml.parsers.expat` — Fast XML parsing using Expat

New in version 2.0. The `xml.parsers.expat` module is a Python interface to the Expat non-validating XML parser. The module provides a single extension type, `xmlparser`, that represents the current state of an XML parser. After an `xmlparser` object has been created, various attributes of the object can be set to handler functions. When an XML document is then fed to the parser, the handler functions are called for the character data and markup in the XML document.

This module uses the `pyexpat` module to provide access to the Expat parser. Direct use of the `pyexpat` module is deprecated.

This module provides one exception and one type object:

**exception** `xml.parsers.expat.ExpatError`

The exception raised when Expat reports an error. See section *ExpatError Exceptions* for more information on interpreting Expat errors.

**exception** `xml.parsers.expat.error`

Alias for `ExpatError`.

`xml.parsers.expat.XMLParserType`

The type of the return values from the `ParserCreate()` function.

The `xml.parsers.expat` module contains two functions:

`xml.parsers.expat.ErrorString(errno)`

Returns an explanatory string for a given error number `errno`.

`xml.parsers.expat.ParserCreate([encoding[, namespace_separator]])`

Creates and returns a new `xmlparser` object. `encoding`, if specified, must be a string naming the encoding used by the XML data. Expat doesn't support as many encodings as Python does, and its repertoire of encodings can't be extended; it supports UTF-8, UTF-16, ISO-8859-1 (Latin1), and ASCII. If `encoding`<sup>3</sup> is given it will override the implicit or explicit encoding of the document.

Expat can optionally do XML namespace processing for you, enabled by providing a value for `namespace_separator`. The value must be a one-character string; a `ValueError` will be raised if the string has an illegal length (None is considered the same as omission). When namespace processing is enabled, element type names and attribute names that belong to a namespace will be expanded. The element name passed to the element handlers `StartElementHandler` and `EndElementHandler` will be the concatenation of the namespace URI, the namespace separator character, and the local part of the name. If the namespace separator is a zero byte (`chr(0)`) then the namespace URI and the local part will be concatenated without any separator.

For example, if `namespace_separator` is set to a space character (' ') and the following document is parsed:

```
<?xml version="1.0"?>
<root xmlns      = "http://default-namespace.org/"
      xmlns:py   = "http://www.python.org/ns/">
  <py:elem1 />
  <elem2 xmlns="" />
</root>
```

`StartElementHandler` will receive the following strings for each element:

```
http://default-namespace.org/ root
http://www.python.org/ns/ elem1
elem2
```

**See Also:**

**The Expat XML Parser** Home page of the Expat project.

## 19.13.1 XMLParser Objects

`xmlparser` objects have the following methods:

<sup>3</sup> The encoding string included in XML output should conform to the appropriate standards. For example, "UTF-8" is valid, but "UTF8" is not. See <http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl> and <http://www.iana.org/assignments/character-sets>.

`xmlparser.Parse(data[, isfinal])`

Parses the contents of the string `data`, calling the appropriate handler functions to process the parsed data. `isfinal` must be true on the final call to this method. `data` can be the empty string at any time.

`xmlparser.ParseFile(file)`

Parse XML data reading from the object `file`. `file` only needs to provide the `read(nbytes)` method, returning the empty string when there's no more data.

`xmlparser.SetBase(base)`

Sets the base to be used for resolving relative URIs in system identifiers in declarations. Resolving relative identifiers is left to the application: this value will be passed through as the `base` argument to the `ExternalEntityRefHandler()`, `NotationDeclHandler()`, and `UnparsedEntityDeclHandler()` functions.

`xmlparser.GetBase()`

Returns a string containing the base set by a previous call to `SetBase()`, or `None` if `SetBase()` hasn't been called.

`xmlparser.GetInputContext()`

Returns the input data that generated the current event as a string. The data is in the encoding of the entity which contains the text. When called while an event handler is not active, the return value is `None`. New in version 2.1.

`xmlparser.ExternalEntityParserCreate(context[, encoding])`

Create a "child" parser which can be used to parse an external parsed entity referred to by content parsed by the parent parser. The `context` parameter should be the string passed to the `ExternalEntityRefHandler()` handler function, described below. The child parser is created with the `ordered_attributes`, `returns_unicode` and `specified_attributes` set to the values of this parser.

`xmlparser.SetParamEntityParsing(flag)`

Control parsing of parameter entities (including the external DTD subset). Possible `flag` values are `XML_PARAM_ENTITY_PARSING_NEVER`, `XML_PARAM_ENTITY_PARSING_UNLESS_STANDALONE` and `XML_PARAM_ENTITY_PARSING_ALWAYS`. Return true if setting the flag was successful.

`xmlparser.UseForeignDTD([flag])`

Calling this with a true value for `flag` (the default) will cause Expat to call the `ExternalEntityRefHandler` with `None` for all arguments to allow an alternate DTD to be loaded. If the document does not contain a document type declaration, the `ExternalEntityRefHandler` will still be called, but the `StartDoctypeDeclHandler` and `EndDoctypeDeclHandler` will not be called.

Passing a false value for `flag` will cancel a previous call that passed a true value, but otherwise has no effect.

This method can only be called before the `Parse()` or `ParseFile()` methods are called; calling it after either of those have been called causes `ExpatriError` to be raised with the `code` attribute set to `errors.XML_ERROR_CANT_CHANGE_FEATURE_ONCE_PARSING`. New in version 2.3.

`xmlparser` objects have the following attributes:

`xmlparser.buffer_size`

The size of the buffer used when `buffer_text` is true. A new buffer size can be set by assigning a new integer value to this attribute. When the size is changed, the buffer will be flushed. New in version 2.3. Changed in version 2.6: The buffer size can now be changed.

`xmlparser.buffer_text`

Setting this to true causes the `xmlparser` object to buffer textual content returned by Expat to avoid multiple calls to the `CharacterDataHandler()` callback whenever possible. This can improve performance substantially since Expat normally breaks character data into chunks at every line ending. This attribute is false by default, and may be changed at any time. New in version 2.3.

**xmlparser.buffer\_used**

If `buffer_text` is enabled, the number of bytes stored in the buffer. These bytes represent UTF-8 encoded text. This attribute has no meaningful interpretation when `buffer_text` is false. New in version 2.3.

**xmlparser.ordered\_attributes**

Setting this attribute to a non-zero integer causes the attributes to be reported as a list rather than a dictionary. The attributes are presented in the order found in the document text. For each attribute, two list entries are presented: the attribute name and the attribute value. (Older versions of this module also used this format.) By default, this attribute is false; it may be changed at any time. New in version 2.1.

**xmlparser.returns\_unicode**

If this attribute is set to a non-zero integer, the handler functions will be passed Unicode strings. If `returns_unicode` is `False`, 8-bit strings containing UTF-8 encoded data will be passed to the handlers. This is `True` by default when Python is built with Unicode support. Changed in version 1.6: Can be changed at any time to affect the result type.

**xmlparser.specified\_attributes**

If set to a non-zero integer, the parser will report only those attributes which were specified in the document instance and not those which were derived from attribute declarations. Applications which set this need to be especially careful to use what additional information is available from the declarations as needed to comply with the standards for the behavior of XML processors. By default, this attribute is false; it may be changed at any time. New in version 2.1.

The following attributes contain values relating to the most recent error encountered by an `xmlparser` object, and will only have correct values once a call to `Parse()` or `ParseFile()` has raised a `xml.parsers.expat.ExpatError` exception.

**xmlparser.ErrorByteIndex**

Byte index at which an error occurred.

**xmlparser.ErrorCode**

Numeric code specifying the problem. This value can be passed to the `ErrorString()` function, or compared to one of the constants defined in the `errors` object.

**xmlparser.ErrorColumnNumber**

Column number at which an error occurred.

**xmlparser.ErrorLineNumber**

Line number at which an error occurred.

The following attributes contain values relating to the current parse location in an `xmlparser` object. During a callback reporting a parse event they indicate the location of the first of the sequence of characters that generated the event. When called outside of a callback, the position indicated will be just past the last parse event (regardless of whether there was an associated callback). New in version 2.4.

**xmlparser.CurrentByteIndex**

Current byte index in the parser input.

**xmlparser.CurrentColumnNumber**

Current column number in the parser input.

**xmlparser.CurrentLineNumber**

Current line number in the parser input.

Here is the list of handlers that can be set. To set a handler on an `xmlparser` object *o*, use `o.handlername = func`. *handlername* must be taken from the following list, and *func* must be a callable object accepting the correct number of arguments. The arguments are all strings, unless otherwise stated.

**xmlparser.XmlDeclHandler** (*version, encoding, standalone*)

Called when the XML declaration is parsed. The XML declaration is the (optional) declaration of the applicable version of the XML recommendation, the encoding of the document text, and an optional “standalone”

declaration. *version* and *encoding* will be strings of the type dictated by the `returns_unicode` attribute, and *standalone* will be 1 if the document is declared standalone, 0 if it is declared not to be standalone, or -1 if the standalone clause was omitted. This is only available with Expat version 1.95.0 or newer. New in version 2.1.

`xmlparser.StartDoctypeDeclHandler` (*doctypeName*, *systemId*, *publicId*, *has\_internal\_subset*)

Called when Expat begins parsing the document type declaration (`<!DOCTYPE . . .`). The *doctypeName* is provided exactly as presented. The *systemId* and *publicId* parameters give the system and public identifiers if specified, or `None` if omitted. *has\_internal\_subset* will be true if the document contains an internal document declaration subset. This requires Expat version 1.2 or newer.

`xmlparser.EndDoctypeDeclHandler` ()

Called when Expat is done parsing the document type declaration. This requires Expat version 1.2 or newer.

`xmlparser.ElementDeclHandler` (*name*, *model*)

Called once for each element type declaration. *name* is the name of the element type, and *model* is a representation of the content model.

`xmlparser.AttnlistDeclHandler` (*elname*, *attname*, *type*, *default*, *required*)

Called for each declared attribute for an element type. If an attribute list declaration declares three attributes, this handler is called three times, once for each attribute. *elname* is the name of the element to which the declaration applies and *attname* is the name of the attribute declared. The attribute type is a string passed as *type*; the possible values are `'CDATA'`, `'ID'`, `'IDREF'`, ... *default* gives the default value for the attribute used when the attribute is not specified by the document instance, or `None` if there is no default value (`#IMPLIED` values). If the attribute is required to be given in the document instance, *required* will be true. This requires Expat version 1.95.0 or newer.

`xmlparser.StartElementHandler` (*name*, *attributes*)

Called for the start of every element. *name* is a string containing the element name, and *attributes* is a dictionary mapping attribute names to their values.

`xmlparser.EndElementHandler` (*name*)

Called for the end of every element.

`xmlparser.ProcessingInstructionHandler` (*target*, *data*)

Called for every processing instruction.

`xmlparser.CharacterDataHandler` (*data*)

Called for character data. This will be called for normal character data, CDATA marked content, and ignorable whitespace. Applications which must distinguish these cases can use the `StartCdataSectionHandler`, `EndCdataSectionHandler`, and `ElementDeclHandler` callbacks to collect the required information.

`xmlparser.UnparsedEntityDeclHandler` (*entityName*, *base*, *systemId*, *publicId*, *notationName*)

Called for unparsed (NDATA) entity declarations. This is only present for version 1.2 of the Expat library; for more recent versions, use `EntityDeclHandler` instead. (The underlying function in the Expat library has been declared obsolete.)

`xmlparser.EntityDeclHandler` (*entityName*, *is\_parameter\_entity*, *value*, *base*, *systemId*, *publicId*, *notationName*)

Called for all entity declarations. For parameter and internal entities, *value* will be a string giving the declared contents of the entity; this will be `None` for external entities. The *notationName* parameter will be `None` for parsed entities, and the name of the notation for unparsed entities. *is\_parameter\_entity* will be true if the entity is a parameter entity or false for general entities (most applications only need to be concerned with general entities). This is only available starting with version 1.95.0 of the Expat library. New in version 2.1.

`xmlparser.NotationDeclHandler` (*notationName*, *base*, *systemId*, *publicId*)

Called for notation declarations. *notationName*, *base*, and *systemId*, and *publicId* are strings if given. If the public identifier is omitted, *publicId* will be `None`.

`xmlparser.StartNamespaceDeclHandler` (*prefix*, *uri*)

Called when an element contains a namespace declaration. Namespace declarations are processed before the

`StartElementHandler` is called for the element on which declarations are placed.

`xmlparser.EndNamespaceDeclHandler` (*prefix*)

Called when the closing tag is reached for an element that contained a namespace declaration. This is called once for each namespace declaration on the element in the reverse of the order for which the `StartNamespaceDeclHandler` was called to indicate the start of each namespace declaration's scope. Calls to this handler are made after the corresponding `EndElementHandler` for the end of the element.

`xmlparser.CommentHandler` (*data*)

Called for comments. *data* is the text of the comment, excluding the leading '`<!--`' and trailing '`-->`'.

`xmlparser.StartCdataSectionHandler` ()

Called at the start of a CDATA section. This and `EndCdataSectionHandler` are needed to be able to identify the syntactical start and end for CDATA sections.

`xmlparser.EndCdataSectionHandler` ()

Called at the end of a CDATA section.

`xmlparser.DefaultHandler` (*data*)

Called for any characters in the XML document for which no applicable handler has been specified. This means characters that are part of a construct which could be reported, but for which no handler has been supplied.

`xmlparser.DefaultHandlerExpand` (*data*)

This is the same as the `DefaultHandler` (), but doesn't inhibit expansion of internal entities. The entity reference will not be passed to the default handler.

`xmlparser.NotStandaloneHandler` ()

Called if the XML document hasn't been declared as being a standalone document. This happens when there is an external subset or a reference to a parameter entity, but the XML declaration does not set `standalone` to `yes` in an XML declaration. If this handler returns 0, then the parser will raise an `XML_ERROR_NOT_STANDALONE` error. If this handler is not set, no exception is raised by the parser for this condition.

`xmlparser.ExternalEntityRefHandler` (*context, base, systemId, publicId*)

Called for references to external entities. *base* is the current base, as set by a previous call to `SetBase` (). The public and system identifiers, *systemId* and *publicId*, are strings if given; if the public identifier is not given, *publicId* will be `None`. The *context* value is opaque and should only be used as described below.

For external entities to be parsed, this handler must be implemented. It is responsible for creating the sub-parser using `ExternalEntityParserCreate` (*context*), initializing it with the appropriate callbacks, and parsing the entity. This handler should return an integer; if it returns 0, the parser will raise an `XML_ERROR_EXTERNAL_ENTITY_HANDLING` error, otherwise parsing will continue.

If this handler is not provided, external entities are reported by the `DefaultHandler` callback, if provided.

## 19.13.2 ExpatError Exceptions

`ExpatError` exceptions have a number of interesting attributes:

`ExpatError.code`

Expat's internal error number for the specific error. This will match one of the constants defined in the `errors` object from this module. New in version 2.1.

`ExpatError.lineno`

Line number on which the error was detected. The first line is numbered 1. New in version 2.1.

`ExpatError.offset`

Character offset into the line where the error occurred. The first column is numbered 0. New in version 2.1.

### 19.13.3 Example

The following program defines three handlers that just print out their arguments.

```
import xml.parsers.expat

# 3 handler functions
def start_element(name, attrs):
    print 'Start element:', name, attrs
def end_element(name):
    print 'End element:', name
def char_data(data):
    print 'Character data:', repr(data)

p = xml.parsers.expat.ParserCreate()

p.StartElementHandler = start_element
p.EndElementHandler = end_element
p.CharacterDataHandler = char_data

p.Parse("""<?xml version="1.0"?>
<parent id="top"><child1 name="paul">Text goes here</child1>
<child2 name="fred">More text</child2>
</parent>""", 1)
```

The output from this program is:

```
Start element: parent {'id': 'top'}
Start element: child1 {'name': 'paul'}
Character data: 'Text goes here'
End element: child1
Character data: '\n'
Start element: child2 {'name': 'fred'}
Character data: 'More text'
End element: child2
Character data: '\n'
End element: parent
```

### 19.13.4 Content Model Descriptions

Content modules are described using nested tuples. Each tuple contains four values: the type, the quantifier, the name, and a tuple of children. Children are simply additional content module descriptions.

The values of the first two fields are constants defined in the `model` object of the `xml.parsers.expat` module. These constants can be collected in two groups: the model type group and the quantifier group.

The constants in the model type group are:

`xml.parsers.expat.XML_CTYPE_ANY`

The element named by the model name was declared to have a content model of ANY.

`xml.parsers.expat.XML_CTYPE_CHOICE`

The named element allows a choice from a number of options; this is used for content models such as (A | B | C).

`xml.parsers.expat.XML_CTYPE_EMPTY`

Elements which are declared to be EMPTY have this model type.

`xml.parsers.expat.XML_CTYPE_MIXED`

`xml.parsers.expat.XML_CTYPE_NAME`

`xml.parsers.expat.XML_CTYPE_SEQ`

Models which represent a series of models which follow one after the other are indicated with this model type. This is used for models such as (A, B, C).

The constants in the quantifier group are:

`xml.parsers.expat.XML_CQUANT_NONE`

No modifier is given, so it can appear exactly once, as for A.

`xml.parsers.expat.XML_CQUANT_OPT`

The model is optional: it can appear once or not at all, as for A?.

`xml.parsers.expat.XML_CQUANT_PLUS`

The model must occur one or more times (like A+).

`xml.parsers.expat.XML_CQUANT_REP`

The model must occur zero or more times, as for A\*.

### 19.13.5 Expat error constants

The following constants are provided in the `errors` object of the `xml.parsers.expat` module. These constants are useful in interpreting some of the attributes of the `ExpatError` exception objects raised when an error has occurred.

The `errors` object has the following attributes:

`xml.parsers.expat.XML_ERROR_ASYNC_ENTITY`

`xml.parsers.expat.XML_ERROR_ATTRIBUTE_EXTERNAL_ENTITY_REF`

An entity reference in an attribute value referred to an external entity instead of an internal entity.

`xml.parsers.expat.XML_ERROR_BAD_CHAR_REF`

A character reference referred to a character which is illegal in XML (for example, character 0, or '&#0;').

`xml.parsers.expat.XML_ERROR_BINARY_ENTITY_REF`

An entity reference referred to an entity which was declared with a notation, so cannot be parsed.

`xml.parsers.expat.XML_ERROR_DUPLICATE_ATTRIBUTE`

An attribute was used more than once in a start tag.

`xml.parsers.expat.XML_ERROR_INCORRECT_ENCODING`

`xml.parsers.expat.XML_ERROR_INVALID_TOKEN`

Raised when an input byte could not properly be assigned to a character; for example, a NUL byte (value 0) in a UTF-8 input stream.

`xml.parsers.expat.XML_ERROR_JUNK_AFTER_DOC_ELEMENT`

Something other than whitespace occurred after the document element.

`xml.parsers.expat.XML_ERROR_MISPLACED_XML_PI`

An XML declaration was found somewhere other than the start of the input data.

`xml.parsers.expat.XML_ERROR_NO_ELEMENTS`

The document contains no elements (XML requires all documents to contain exactly one top-level element)..

`xml.parsers.expat.XML_ERROR_NO_MEMORY`

Expat was not able to allocate memory internally.

- `xml.parsers.expat.XML_ERROR_PARAM_ENTITY_REF`  
A parameter entity reference was found where it was not allowed.
- `xml.parsers.expat.XML_ERROR_PARTIAL_CHAR`  
An incomplete character was found in the input.
- `xml.parsers.expat.XML_ERROR_RECURSIVE_ENTITY_REF`  
An entity reference contained another reference to the same entity; possibly via a different name, and possibly indirectly.
- `xml.parsers.expat.XML_ERROR_SYNTAX`  
Some unspecified syntax error was encountered.
- `xml.parsers.expat.XML_ERROR_TAG_MISMATCH`  
An end tag did not match the innermost open start tag.
- `xml.parsers.expat.XML_ERROR_UNCLOSED_TOKEN`  
Some token (such as a start tag) was not closed before the end of the stream or the next token was encountered.
- `xml.parsers.expat.XML_ERROR_UNDEFINED_ENTITY`  
A reference was made to a entity which was not defined.
- `xml.parsers.expat.XML_ERROR_UNKNOWN_ENCODING`  
The document encoding is not supported by Expat.
- `xml.parsers.expat.XML_ERROR_UNCLOSED_CDATA_SECTION`  
A CDATA marked section was not closed.
- `xml.parsers.expat.XML_ERROR_EXTERNAL_ENTITY_HANDLING`
- `xml.parsers.expat.XML_ERROR_NOT_STANDALONE`  
The parser determined that the document was not “standalone” though it declared itself to be in the XML declaration, and the `NotStandaloneHandler` was set and returned 0.
- `xml.parsers.expat.XML_ERROR_UNEXPECTED_STATE`
- `xml.parsers.expat.XML_ERROR_ENTITY_DECLARED_IN_PE`
- `xml.parsers.expat.XML_ERROR_FEATURE_REQUIRES_XML_DTD`  
An operation was requested that requires DTD support to be compiled in, but Expat was configured without DTD support. This should never be reported by a standard build of the `xml.parsers.expat` module.
- `xml.parsers.expat.XML_ERROR_CANT_CHANGE_FEATURE_ONCE_PARSING`  
A behavioral change was requested after parsing started that can only be changed before parsing has started. This is (currently) only raised by `UseForeignDTD()`.
- `xml.parsers.expat.XML_ERROR_UNBOUND_PREFIX`  
An undeclared prefix was found when namespace processing was enabled.
- `xml.parsers.expat.XML_ERROR_UNDECLARING_PREFIX`  
The document attempted to remove the namespace declaration associated with a prefix.
- `xml.parsers.expat.XML_ERROR_INCOMPLETE_PE`  
A parameter entity contained incomplete markup.
- `xml.parsers.expat.XML_ERROR_XML_DECL`  
The document contained no document element at all.
- `xml.parsers.expat.XML_ERROR_TEXT_DECL`  
There was an error parsing a text declaration in an external entity.
- `xml.parsers.expat.XML_ERROR_PUBLICID`  
Characters were found in the public id that are not allowed.

`xml.parsers.expat.XML_ERROR_SUSPENDED`

The requested operation was made on a suspended parser, but isn't allowed. This includes attempts to provide additional input or to stop the parser.

`xml.parsers.expat.XML_ERROR_NOT_SUSPENDED`

An attempt to resume the parser was made when the parser had not been suspended.

`xml.parsers.expat.XML_ERROR_ABORTED`

This should not be reported to Python applications.

`xml.parsers.expat.XML_ERROR_FINISHED`

The requested operation was made on a parser which was finished parsing input, but isn't allowed. This includes attempts to provide additional input or to stop the parser.

`xml.parsers.expat.XML_ERROR_SUSPEND_PE`



# INTERNET PROTOCOLS AND SUPPORT

The modules described in this chapter implement Internet protocols and support for related technology. They are all implemented in Python. Most of these modules require the presence of the system-dependent module `socket`, which is currently supported on most popular platforms. Here is an overview:

## 20.1 `webbrowser` — Convenient Web-browser controller

**Source code:** [Lib/webbrowser.py](#)

---

The `webbrowser` module provides a high-level interface to allow displaying Web-based documents to users. Under most circumstances, simply calling the `open()` function from this module will do the right thing.

Under Unix, graphical browsers are preferred under X11, but text-mode browsers will be used if graphical browsers are not available or an X11 display isn't available. If text-mode browsers are used, the calling process will block until the user exits the browser.

If the environment variable `BROWSER` exists, it is interpreted to override the platform default list of browsers, as a `os.pathsep`-separated list of browsers to try in order. When the value of a list part contains the string `%s`, then it is interpreted as a literal browser command line to be used with the argument URL substituted for `%s`; if the part does not contain `%s`, it is simply interpreted as the name of the browser to launch.<sup>1</sup>

For non-Unix platforms, or when a remote browser is available on Unix, the controlling process will not wait for the user to finish with the browser, but allow the remote browser to maintain its own windows on the display. If remote browsers are not available on Unix, the controlling process will launch a new browser and wait.

The script `webbrowser` can be used as a command-line interface for the module. It accepts an URL as the argument. It accepts the following optional parameters: `-n` opens the URL in a new browser window, if possible; `-t` opens the URL in a new browser page ("tab"). The options are, naturally, mutually exclusive. Usage example:

```
python -m webbrowser -t "http://www.python.org"
```

The following exception is defined:

**exception `webbrowser.Error`**

Exception raised when a browser control error occurs.

The following functions are defined:

---

<sup>1</sup> Executables named here without a full path will be searched in the directories given in the `PATH` environment variable.

`webbrowser.open(url, new=0, autoraise=True)`

Display *url* using the default browser. If *new* is 0, the *url* is opened in the same browser window if possible. If *new* is 1, a new browser window is opened if possible. If *new* is 2, a new browser page (“tab”) is opened if possible. If *autoraise* is `True`, the window is raised if possible (note that under many window managers this will occur regardless of the setting of this variable).

Note that on some platforms, trying to open a filename using this function, may work and start the operating system’s associated program. However, this is neither supported nor portable. Changed in version 2.5: *new* can now be 2.

`webbrowser.open_new(url)`

Open *url* in a new window of the default browser, if possible, otherwise, open *url* in the only browser window.

`webbrowser.open_new_tab(url)`

Open *url* in a new page (“tab”) of the default browser, if possible, otherwise equivalent to `open_new()`. New in version 2.5.

`webbrowser.get([name])`

Return a controller object for the browser type *name*. If *name* is empty, return a controller for a default browser appropriate to the caller’s environment.

`webbrowser.register(name, constructor[, instance])`

Register the browser type *name*. Once a browser type is registered, the `get()` function can return a controller for that browser type. If *instance* is not provided, or is `None`, *constructor* will be called without parameters to create an instance when needed. If *instance* is provided, *constructor* will never be called, and may be `None`.

This entry point is only useful if you plan to either set the `BROWSER` variable or call `get()` with a nonempty argument matching the name of a handler you declare.

A number of browser types are predefined. This table gives the type names that may be passed to the `get()` function and the corresponding instantiations for the controller classes, all defined in this module.

Type Name	Class Name	Notes
'mozilla'	Mozilla('mozilla')	
'firefox'	Mozilla('mozilla')	
'netscape'	Mozilla('netscape')	
'galeon'	Galeon('galeon')	
'epiphany'	Galeon('epiphany')	
'skipstone'	BackgroundBrowser('skipstone')	
'kfmclient'	Konqueror()	(1)
'konqueror'	Konqueror()	(1)
'kfm'	Konqueror()	(1)
'mosaic'	BackgroundBrowser('mosaic')	
'opera'	Opera()	
'grail'	Grail()	
'links'	GenericBrowser('links')	
'elinks'	Elinks('elinks')	
'lynx'	GenericBrowser('lynx')	
'w3m'	GenericBrowser('w3m')	
'windows-default'	WindowsDefault	(2)
'macosx'	MacOSX('default')	(3)
'safari'	MacOSX('safari')	(3)

Notes:

1. “Konqueror” is the file manager for the KDE desktop environment for Unix, and only makes sense to use if KDE is running. Some way of reliably detecting KDE would be nice; the `KDEDIR` variable is not sufficient. Note also that the name “kfm” is used even when using the `konqueror` command with KDE 2 — the implementation selects the best strategy for running Konqueror.

2. Only on Windows platforms.
3. Only on Mac OS X platform.

Here are some simple examples:

```
url = 'http://www.python.org/'

# Open URL in a new tab, if a browser window is already open.
webbrowser.open_new_tab(url + 'doc/')

# Open URL in new window, raising the window if possible.
webbrowser.open_new(url)
```

### 20.1.1 Browser Controller Objects

Browser controllers provide these methods which parallel three of the module-level convenience functions:

`controller.open(url, new=0, autoraise=True)`

Display *url* using the browser handled by this controller. If *new* is 1, a new browser window is opened if possible. If *new* is 2, a new browser page (“tab”) is opened if possible.

`controller.open_new(url)`

Open *url* in a new window of the browser handled by this controller, if possible, otherwise, open *url* in the only browser window. Alias `open_new()`.

`controller.open_new_tab(url)`

Open *url* in a new page (“tab”) of the browser handled by this controller, if possible, otherwise equivalent to `open_new()`. New in version 2.5.

## 20.2 cgi — Common Gateway Interface support

**Source code:** [Lib/cgi.py](#)

Support module for Common Gateway Interface (CGI) scripts.

This module defines a number of utilities for use by CGI scripts written in Python.

### 20.2.1 Introduction

A CGI script is invoked by an HTTP server, usually to process user input submitted through an HTML `<FORM>` or `<ISINDEX>` element.

Most often, CGI scripts live in the server’s special `cgi-bin` directory. The HTTP server places all sorts of information about the request (such as the client’s hostname, the requested URL, the query string, and lots of other goodies) in the script’s shell environment, executes the script, and sends the script’s output back to the client.

The script’s input is connected to the client too, and sometimes the form data is read this way; at other times the form data is passed via the “query string” part of the URL. This module is intended to take care of the different cases and provide a simpler interface to the Python script. It also provides a number of utilities that help in debugging scripts, and the latest addition is support for file uploads from a form (if your browser supports it).

The output of a CGI script should consist of two sections, separated by a blank line. The first section contains a number of headers, telling the client what kind of data is following. Python code to generate a minimal header section looks like this:

```
print "Content-Type: text/html"      # HTML is following
print                               # blank line, end of headers
```

The second section is usually HTML, which allows the client software to display nicely formatted text with header, in-line images, etc. Here's Python code that prints a simple piece of HTML:

```
print "<TITLE>CGI script output</TITLE>"
print "<H1>This is my first CGI script</H1>"
print "Hello, world!"
```

### 20.2.2 Using the cgi module

Begin by writing `import cgi`. Do not use `from cgi import *` — the module defines all sorts of names for its own use or for backward compatibility that you don't want in your namespace.

When you write a new script, consider adding these lines:

```
import cgitb
cgitb.enable()
```

This activates a special exception handler that will display detailed reports in the Web browser if any errors occur. If you'd rather not show the guts of your program to users of your script, you can have the reports saved to files instead, with code like this:

```
import cgitb
cgitb.enable(display=0, logdir="/tmp")
```

It's very helpful to use this feature during script development. The reports produced by `cgitb` provide information that can save you a lot of time in tracking down bugs. You can always remove the `cgitb` line later when you have tested your script and are confident that it works correctly.

To get at submitted form data, it's best to use the `FieldStorage` class. The other classes defined in this module are provided mostly for backward compatibility. Instantiate it exactly once, without arguments. This reads the form contents from standard input or the environment (depending on the value of various environment variables set according to the CGI standard). Since it may consume standard input, it should be instantiated only once.

The `FieldStorage` instance can be indexed like a Python dictionary. It allows membership testing with the `in` operator, and also supports the standard dictionary method `keys()` and the built-in function `len()`. Form fields containing empty strings are ignored and do not appear in the dictionary; to keep such values, provide a true value for the optional `keep_blank_values` keyword parameter when creating the `FieldStorage` instance.

For instance, the following code (which assumes that the `Content-Type` header and blank line have already been printed) checks that the fields `name` and `addr` are both set to a non-empty string:

```
form = cgi.FieldStorage()
if "name" not in form or "addr" not in form:
    print "<H1>Error</H1>"
    print "Please fill in the name and addr fields."
    return
print "<p>name:", form["name"].value
print "<p>addr:", form["addr"].value
...further form processing here...
```

Here the fields, accessed through `form[key]`, are themselves instances of `FieldStorage` (or `MiniFieldStorage`, depending on the form encoding). The `value` attribute of the instance yields the string value of the field. The `getvalue()` method returns this string value directly; it also accepts an optional second argument as a default to return if the requested key is not present.

If the submitted form data contains more than one field with the same name, the object retrieved by `form[key]` is not a `FieldStorage` or `MiniFieldStorage` instance but a list of such instances. Similarly, in this situation,

`form.getvalue(key)` would return a list of strings. If you expect this possibility (when your HTML form contains multiple fields with the same name), use the `getlist()` function, which always returns a list of values (so that you do not need to special-case the single item case). For example, this code concatenates any number of username fields, separated by commas:

```
value = form.getlist("username")
usernames = ",".join(value)
```

If a field represents an uploaded file, accessing the value via the `value` attribute or the `getvalue()` method reads the entire file in memory as a string. This may not be what you want. You can test for an uploaded file by testing either the `filename` attribute or the `file` attribute. You can then read the data at leisure from the `file` attribute:

```
fileitem = form["userfile"]
if fileitem.file:
    # It's an uploaded file; count lines
    linecount = 0
    while 1:
        line = fileitem.file.readline()
        if not line: break
        linecount = linecount + 1
```

If an error is encountered when obtaining the contents of an uploaded file (for example, when the user interrupts the form submission by clicking on a Back or Cancel button) the `done` attribute of the object for the field will be set to the value `-1`.

The file upload draft standard entertains the possibility of uploading multiple files from one field (using a recursive *multipart/\** encoding). When this occurs, the item will be a dictionary-like `FieldStorage` item. This can be determined by testing its `type` attribute, which should be *multipart/form-data* (or perhaps another MIME type matching *multipart/\**). In this case, it can be iterated over recursively just like the top-level form object.

When a form is submitted in the “old” format (as the query string or as a single data part of type *application/x-www-form-urlencoded*), the items will actually be instances of the class `MiniFieldStorage`. In this case, the `list`, `file`, and `filename` attributes are always `None`.

A form submitted via POST that also has a query string will contain both `FieldStorage` and `MiniFieldStorage` items.

### 20.2.3 Higher Level Interface

New in version 2.2. The previous section explains how to read CGI form data using the `FieldStorage` class. This section describes a higher level interface which was added to this class to allow one to do it in a more readable and intuitive way. The interface doesn’t make the techniques described in previous sections obsolete — they are still useful to process file uploads efficiently, for example.

The interface consists of two simple methods. Using the methods you can process form data in a generic way, without the need to worry whether only one or more values were posted under one name.

In the previous section, you learned to write following code anytime you expected a user to post more than one value under one name:

```
item = form.getvalue("item")
if isinstance(item, list):
    # The user is requesting more than one item.
else:
    # The user is requesting only one item.
```

This situation is common for example when a form contains a group of multiple checkboxes with the same name:

```
<input type="checkbox" name="item" value="1" />
<input type="checkbox" name="item" value="2" />
```

In most situations, however, there's only one form control with a particular name in a form and then you expect and need only one value associated with this name. So you write a script containing for example this code:

```
user = form.getvalue("user").upper()
```

The problem with the code is that you should never expect that a client will provide valid input to your scripts. For example, if a curious user appends another `user=foo` pair to the query string, then the script would crash, because in this situation the `getvalue("user")` method call returns a list instead of a string. Calling the `upper()` method on a list is not valid (since lists do not have a method of this name) and results in an `AttributeError` exception.

Therefore, the appropriate way to read form data values was to always use the code which checks whether the obtained value is a single value or a list of values. That's annoying and leads to less readable scripts.

A more convenient approach is to use the methods `getfirst()` and `getlist()` provided by this higher level interface.

`FieldStorage.getfirst(name[, default])`

This method always returns only one value associated with form field *name*. The method returns only the first value in case that more values were posted under such name. Please note that the order in which the values are received may vary from browser to browser and should not be counted on.<sup>2</sup> If no such form field or value exists then the method returns the value specified by the optional parameter *default*. This parameter defaults to `None` if not specified.

`FieldStorage.getlist(name)`

This method always returns a list of values associated with form field *name*. The method returns an empty list if no such form field or value exists for *name*. It returns a list consisting of one item if only one such value exists.

Using these methods you can write nice compact code:

```
import cgi
form = cgi.FieldStorage()
user = form.getfirst("user", "").upper()    # This way it's safe.
for item in form.getlist("item"):
    do_something(item)
```

### 20.2.4 Old classes

Deprecated since version 2.6. `SvFormContentDict` stores single value form content as dictionary; it assumes each field name occurs in the form only once.

`FormContentDict` stores multiple value form content as a dictionary (the form items are lists of values). Useful if your form contains multiple fields with the same name.

Other classes (`FormContent`, `InterpFormContentDict`) are present for backwards compatibility with really old applications only.

### 20.2.5 Functions

These are useful if you want more control, or if you want to employ some of the algorithms implemented in this module in other circumstances.

---

<sup>2</sup> Note that some recent versions of the HTML specification do state what order the field values should be supplied in, but knowing whether a request was received from a conforming browser, or even from a browser at all, is tedious and error-prone.

`cgi.parse(fp[, environ[, keep_blank_values[, strict_parsing]]])`  
 Parse a query in the environment or from a file (the file defaults to `sys.stdin` and environment defaults to `os.environ`). The `keep_blank_values` and `strict_parsing` parameters are passed to `urlparse.parse_qs()` unchanged.

`cgi.parse_qs(qs[, keep_blank_values[, strict_parsing]])`  
 This function is deprecated in this module. Use `urlparse.parse_qs()` instead. It is maintained here only for backward compatibility.

`cgi.parse_qs1(qs[, keep_blank_values[, strict_parsing]])`  
 This function is deprecated in this module. Use `urlparse.parse_qs1()` instead. It is maintained here only for backward compatibility.

`cgi.parse_multipart(fp, pdict)`  
 Parse input of type *multipart/form-data* (for file uploads). Arguments are `fp` for the input file and `pdict` for a dictionary containing other parameters in the *Content-Type* header.

Returns a dictionary just like `urlparse.parse_qs()` keys are the field names, each value is a list of values for that field. This is easy to use but not much good if you are expecting megabytes to be uploaded — in that case, use the `FieldStorage` class instead which is much more flexible.

Note that this does not parse nested multipart parts — use `FieldStorage` for that.

`cgi.parse_header(string)`  
 Parse a MIME header (such as *Content-Type*) into a main value and a dictionary of parameters.

`cgi.test()`  
 Robust test CGI script, usable as main program. Writes minimal HTTP headers and formats all information provided to the script in HTML form.

`cgi.print_envIRON()`  
 Format the shell environment in HTML.

`cgi.print_form(form)`  
 Format a form in HTML.

`cgi.print_directory()`  
 Format the current directory in HTML.

`cgi.print_envIRON_usage()`  
 Print a list of useful (used by CGI) environment variables in HTML.

`cgi.escape(s[, quote])`  
 Convert the characters `'&'`, `'<'` and `'>'` in string `s` to HTML-safe sequences. Use this if you need to display text that might contain such characters in HTML. If the optional flag `quote` is true, the quotation mark character (`"`) is also translated; this helps for inclusion in an HTML attribute value delimited by double quotes, as in `<a href=" . . . ">`. Note that single quotes are never translated.

If the value to be quoted might include single- or double-quote characters, or both, consider using the `quoteattr()` function in the `xml.sax.saxutils` module instead.

## 20.2.6 Caring about security

There's one important rule: if you invoke an external program (via the `os.system()` or `os.popen()` functions, or others with similar functionality), make very sure you don't pass arbitrary strings received from the client to the shell. This is a well-known security hole whereby clever hackers anywhere on the Web can exploit a gullible CGI script to invoke arbitrary shell commands. Even parts of the URL or field names cannot be trusted, since the request doesn't have to come from your form!

To be on the safe side, if you must pass a string gotten from a form to a shell command, you should make sure the string contains only alphanumeric characters, dashes, underscores, and periods.

### 20.2.7 Installing your CGI script on a Unix system

Read the documentation for your HTTP server and check with your local system administrator to find the directory where CGI scripts should be installed; usually this is in a directory `cgi-bin` in the server tree.

Make sure that your script is readable and executable by “others”; the Unix file mode should be 0755 octal (use `chmod 0755 filename`). Make sure that the first line of the script contains `#!` starting in column 1 followed by the pathname of the Python interpreter, for instance:

```
#!/usr/local/bin/python
```

Make sure the Python interpreter exists and is executable by “others”.

Make sure that any files your script needs to read or write are readable or writable, respectively, by “others” — their mode should be 0644 for readable and 0666 for writable. This is because, for security reasons, the HTTP server executes your script as user “nobody”, without any special privileges. It can only read (write, execute) files that everybody can read (write, execute). The current directory at execution time is also different (it is usually the server’s `cgi-bin` directory) and the set of environment variables is also different from what you get when you log in. In particular, don’t count on the shell’s search path for executables (`PATH`) or the Python module search path (`PYTHONPATH`) to be set to anything interesting.

If you need to load modules from a directory which is not on Python’s default module search path, you can change the path in your script, before importing other modules. For example:

```
import sys
sys.path.insert(0, "/usr/home/joe/lib/python")
sys.path.insert(0, "/usr/local/lib/python")
```

(This way, the directory inserted last will be searched first!)

Instructions for non-Unix systems will vary; check your HTTP server’s documentation (it will usually have a section on CGI scripts).

### 20.2.8 Testing your CGI script

Unfortunately, a CGI script will generally not run when you try it from the command line, and a script that works perfectly from the command line may fail mysteriously when run from the server. There’s one reason why you should still test your script from the command line: if it contains a syntax error, the Python interpreter won’t execute it at all, and the HTTP server will most likely send a cryptic error to the client.

Assuming your script has no syntax errors, yet it does not work, you have no choice but to read the next section.

### 20.2.9 Debugging CGI scripts

First of all, check for trivial installation errors — reading the section above on installing your CGI script carefully can save you a lot of time. If you wonder whether you have understood the installation procedure correctly, try installing a copy of this module file (`cgi.py`) as a CGI script. When invoked as a script, the file will dump its environment and the contents of the form in HTML form. Give it the right mode etc, and send it a request. If it’s installed in the standard `cgi-bin` directory, it should be possible to send it a request by entering a URL into your browser of the form:

```
http://yourhostname/cgi-bin/cgi.py?name=Joe+Blow&addr=At+Home
```

If this gives an error of type 404, the server cannot find the script – perhaps you need to install it in a different directory. If it gives another error, there’s an installation problem that you should fix before trying to go any further. If you get a nicely formatted listing of the environment and form content (in this example, the fields should be listed as “addr” with value “At Home” and “name” with value “Joe Blow”), the `cgi.py` script has been installed correctly. If you follow the same procedure for your own script, you should now be able to debug it.

The next step could be to call the `cgi` module’s `test()` function from your script: replace its main code with the single statement

```
cgi.test()
```

This should produce the same results as those gotten from installing the `cgi.py` file itself.

When an ordinary Python script raises an unhandled exception (for whatever reason: of a typo in a module name, a file that can’t be opened, etc.), the Python interpreter prints a nice traceback and exits. While the Python interpreter will still do this when your CGI script raises an exception, most likely the traceback will end up in one of the HTTP server’s log files, or be discarded altogether.

Fortunately, once you have managed to get your script to execute *some* code, you can easily send tracebacks to the Web browser using the `cgitb` module. If you haven’t done so already, just add the lines:

```
import cgitb
cgitb.enable()
```

to the top of your script. Then try running it again; when a problem occurs, you should see a detailed report that will likely make apparent the cause of the crash.

If you suspect that there may be a problem in importing the `cgitb` module, you can use an even more robust approach (which only uses built-in modules):

```
import sys
sys.stderr = sys.stdout
print "Content-Type: text/plain"
print
...your code here...
```

This relies on the Python interpreter to print the traceback. The content type of the output is set to plain text, which disables all HTML processing. If your script works, the raw HTML will be displayed by your client. If it raises an exception, most likely after the first two lines have been printed, a traceback will be displayed. Because no HTML interpretation is going on, the traceback will be readable.

## 20.2.10 Common problems and solutions

- Most HTTP servers buffer the output from CGI scripts until the script is completed. This means that it is not possible to display a progress report on the client’s display while the script is running.
- Check the installation instructions above.
- Check the HTTP server’s log files. (`tail -f logfile` in a separate window may be useful!)
- Always check a script for syntax errors first, by doing something like `python script.py`.
- If your script does not have any syntax errors, try adding `import cgitb; cgitb.enable()` to the top of the script.
- When invoking external programs, make sure they can be found. Usually, this means using absolute path names — `PATH` is usually not set to a very useful value in a CGI script.
- When reading or writing external files, make sure they can be read or written by the `userid` under which your CGI script will be running: this is typically the `userid` under which the web server is running, or some explicitly specified `userid` for a web server’s `suxexec` feature.

- Don't try to give a CGI script a set-uid mode. This doesn't work on most systems, and is a security liability as well.

## 20.3 `cgitb` — Traceback manager for CGI scripts

New in version 2.2. The `cgitb` module provides a special exception handler for Python scripts. (Its name is a bit misleading. It was originally designed to display extensive traceback information in HTML for CGI scripts. It was later generalized to also display this information in plain text.) After this module is activated, if an uncaught exception occurs, a detailed, formatted report will be displayed. The report includes a traceback showing excerpts of the source code for each level, as well as the values of the arguments and local variables to currently running functions, to help you debug the problem. Optionally, you can save this information to a file instead of sending it to the browser.

To enable this feature, simply add this to the top of your CGI script:

```
import cgitb
cgitb.enable()
```

The options to the `enable()` function control whether the report is displayed in the browser and whether the report is logged to a file for later analysis.

```
cgitb.enable([display[, logdir[, context[, format ]]])])
```

This function causes the `cgitb` module to take over the interpreter's default handling for exceptions by setting the value of `sys.excepthook`.

The optional argument `display` defaults to 1 and can be set to 0 to suppress sending the traceback to the browser. If the argument `logdir` is present, the traceback reports are written to files. The value of `logdir` should be a directory where these files will be placed. The optional argument `context` is the number of lines of context to display around the current line of source code in the traceback; this defaults to 5. If the optional argument `format` is "html", the output is formatted as HTML. Any other value forces plain text output. The default value is "html".

```
cgitb.handler([info])
```

This function handles an exception using the default settings (that is, show a report in the browser, but don't log to a file). This can be used when you've caught an exception and want to report it using `cgitb`. The optional `info` argument should be a 3-tuple containing an exception type, exception value, and traceback object, exactly like the tuple returned by `sys.exc_info()`. If the `info` argument is not supplied, the current exception is obtained from `sys.exc_info()`.

## 20.4 `wsgiref` — WSGI Utilities and Reference Implementation

New in version 2.5. The Web Server Gateway Interface (WSGI) is a standard interface between web server software and web applications written in Python. Having a standard interface makes it easy to use an application that supports WSGI with a number of different web servers.

Only authors of web servers and programming frameworks need to know every detail and corner case of the WSGI design. You don't need to understand every detail of WSGI just to install a WSGI application or to write a web application using an existing framework.

`wsgiref` is a reference implementation of the WSGI specification that can be used to add WSGI support to a web server or framework. It provides utilities for manipulating WSGI environment variables and response headers, base classes for implementing WSGI servers, a demo HTTP server that serves WSGI applications, and a validation tool that checks WSGI servers and applications for conformance to the WSGI specification ( [PEP 333](#) ).

See <http://www.wsgi.org> for more information about WSGI, and links to tutorials and other resources.

## 20.4.1 wsgiref.util – WSGI environment utilities

This module provides a variety of utility functions for working with WSGI environments. A WSGI environment is a dictionary containing HTTP request variables as described in [PEP 333](#). All of the functions taking an *environ* parameter expect a WSGI-compliant dictionary to be supplied; please see

[PEP 333](#) for a detailed specification.

`wsgiref.util.guess_scheme(environ)`

Return a guess for whether `wsgi.url_scheme` should be “http” or “https”, by checking for a HTTPS environment variable in the *environ* dictionary. The return value is a string.

This function is useful when creating a gateway that wraps CGI or a CGI-like protocol such as FastCGI. Typically, servers providing such protocols will include a `HTTPS` variable with a value of “1” “yes”, or “on” when a request is received via SSL. So, this function returns “https” if such a value is found, and “http” otherwise.

`wsgiref.util.request_uri(environ, include_query=1)`

Return the full request URI, optionally including the query string, using the algorithm found in the “URL Reconstruction” section of [PEP 333](#). If *include\_query* is false, the query string is not included in the resulting URI.

`wsgiref.util.application_uri(environ)`

Similar to `request_uri()`, except that the `PATH_INFO` and `QUERY_STRING` variables are ignored. The result is the base URI of the application object addressed by the request.

`wsgiref.util.shift_path_info(environ)`

Shift a single name from `PATH_INFO` to `SCRIPT_NAME` and return the name. The *environ* dictionary is *modified* in-place; use a copy if you need to keep the original `PATH_INFO` or `SCRIPT_NAME` intact.

If there are no remaining path segments in `PATH_INFO`, `None` is returned.

Typically, this routine is used to process each portion of a request URI path, for example to treat the path as a series of dictionary keys. This routine modifies the passed-in environment to make it suitable for invoking another WSGI application that is located at the target URI. For example, if there is a WSGI application at `/foo`, and the request URI path is `/foo/bar/baz`, and the WSGI application at `/foo` calls `shift_path_info()`, it will receive the string “bar”, and the environment will be updated to be suitable for passing to a WSGI application at `/foo/bar`. That is, `SCRIPT_NAME` will change from `/foo` to `/foo/bar`, and `PATH_INFO` will change from `/bar/baz` to `/baz`.

When `PATH_INFO` is just a “/”, this routine returns an empty string and appends a trailing slash to `SCRIPT_NAME`, even though empty path segments are normally ignored, and `SCRIPT_NAME` doesn’t normally end in a slash. This is intentional behavior, to ensure that an application can tell the difference between URIs ending in `/x` from ones ending in `/x/` when using this routine to do object traversal.

`wsgiref.util.setup_testing_defaults(environ)`

Update *environ* with trivial defaults for testing purposes.

This routine adds various parameters required for WSGI, including `HTTP_HOST`, `SERVER_NAME`, `SERVER_PORT`, `REQUEST_METHOD`, `SCRIPT_NAME`, `PATH_INFO`, and all of the [PEP 333](#)-defined `wsgi.*` variables. It only supplies default values, and does not replace any existing settings for these variables.

This routine is intended to make it easier for unit tests of WSGI servers and applications to set up dummy environments. It should NOT be used by actual WSGI servers or applications, since the data is fake!

Example usage:

```
from wsgiref.util import setup_testing_defaults
from wsgiref.simple_server import make_server
```

```
# A relatively simple WSGI application. It's going to print out the
# environment dictionary after being updated by setup_testing_defaults
def simple_app(environ, start_response):
    setup_testing_defaults(environ)

    status = '200 OK'
    headers = [('Content-type', 'text/plain')]

    start_response(status, headers)

    ret = ["%s: %s\n" % (key, value)
           for key, value in environ.iteritems()]
    return ret

httpd = make_server('', 8000, simple_app)
print "Serving on port 8000..."
httpd.serve_forever()
```

In addition to the environment functions above, the `wsgiref.util` module also provides these miscellaneous utilities:

`wsgiref.util.is_hop_by_hop(header_name)`

Return true if 'header\_name' is an HTTP/1.1 "Hop-by-Hop" header, as defined by

**RFC 2616.**

**class** `wsgiref.util.FileWrapper` (*filelike*, *blksize=8192*)

A wrapper to convert a file-like object to an *iterator*. The resulting objects support both `__getitem__()` and `__iter__()` iteration styles, for compatibility with Python 2.1 and Jython. As the object is iterated over, the optional *blksize* parameter will be repeatedly passed to the *filelike* object's `read()` method to obtain strings to yield. When `read()` returns an empty string, iteration is ended and is not resumable.

If *filelike* has a `close()` method, the returned object will also have a `close()` method, and it will invoke the *filelike* object's `close()` method when called.

Example usage:

```
from StringIO import StringIO
from wsgiref.util import FileWrapper

# We're using a StringIO-buffer for as the file-like object
filelike = StringIO("This is an example file-like object"*10)
wrapper = FileWrapper(filelike, blksize=5)

for chunk in wrapper:
    print chunk
```

## 20.4.2 `wsgiref.headers` – WSGI response header tools

This module provides a single class, `Headers`, for convenient manipulation of WSGI response headers using a mapping-like interface.

**class** `wsgiref.headers.Headers` (*headers*)

Create a mapping-like object wrapping *headers*, which must be a list of header name/value tuples as described in **PEP 333**. Any changes made to the new `Headers` object will directly update the *headers* list it was created with.

`Headers` objects support typical mapping operations including `__getitem__()`, `get()`, `__setitem__()`, `setdefault()`, `__delitem__()`, `__contains__()` and `has_key()`. For each of these methods, the key is the header name (treated case-insensitively), and the value is the first value associated with that header name. Setting a header deletes any existing values for that header, then adds a new value at the end of the wrapped header list. Headers' existing order is generally maintained, with new headers added to the end of the wrapped list.

Unlike a dictionary, `Headers` objects do not raise an error when you try to get or delete a key that isn't in the wrapped header list. Getting a nonexistent header just returns `None`, and deleting a nonexistent header does nothing.

`Headers` objects also support `keys()`, `values()`, and `items()` methods. The lists returned by `keys()` and `items()` can include the same key more than once if there is a multi-valued header. The `len()` of a `Headers` object is the same as the length of its `items()`, which is the same as the length of the wrapped header list. In fact, the `items()` method just returns a copy of the wrapped header list.

Calling `str()` on a `Headers` object returns a formatted string suitable for transmission as HTTP response headers. Each header is placed on a line with its value, separated by a colon and a space. Each line is terminated by a carriage return and line feed, and the string is terminated with a blank line.

In addition to their mapping interface and formatting features, `Headers` objects also have the following methods for querying and adding multi-valued headers, and for adding headers with MIME parameters:

**`get_all(name)`**

Return a list of all the values for the named header.

The returned list will be sorted in the order they appeared in the original header list or were added to this instance, and may contain duplicates. Any fields deleted and re-inserted are always appended to the header list. If no fields exist with the given name, returns an empty list.

**`add_header(name, value, **_params)`**

Add a (possibly multi-valued) header, with optional MIME parameters specified via keyword arguments.

`name` is the header field to add. Keyword arguments can be used to set MIME parameters for the header field. Each parameter must be a string or `None`. Underscores in parameter names are converted to dashes, since dashes are illegal in Python identifiers, but many MIME parameter names include dashes. If the parameter value is a string, it is added to the header value parameters in the form `name="value"`. If it is `None`, only the parameter name is added. (This is used for MIME parameters without a value.) Example usage:

```
h.add_header('content-disposition', 'attachment', filename='bud.gif')
```

The above will add a header that looks like this:

```
Content-Disposition: attachment; filename="bud.gif"
```

### 20.4.3 `wsgiref.simple_server` – a simple WSGI HTTP server

This module implements a simple HTTP server (based on `BaseHTTPServer`) that serves WSGI applications. Each server instance serves a single WSGI application on a given host and port. If you want to serve multiple applications on a single host and port, you should create a WSGI application that parses `PATH_INFO` to select which application to invoke for each request. (E.g., using the `shift_path_info()` function from `wsgiref.util`.)

```
wsgiref.simple_server.make_server(host, port, app, server_class=WSGIServer, handler_class=WSGIRequestHandler)
```

Create a new WSGI server listening on `host` and `port`, accepting connections for `app`. The return value is an instance of the supplied `server_class`, and will process requests using the specified `handler_class`. `app` must be a WSGI application object, as defined by [PEP 333](#).

Example usage:

```
from wsgiref.simple_server import make_server, demo_app

httpd = make_server('', 8000, demo_app)
print "Serving HTTP on port 8000..."

# Respond to requests until process is killed
httpd.serve_forever()

# Alternative: serve one request, then exit
httpd.handle_request()
```

`wsgiref.simple_server.demo_app` (*environ*, *start\_response*)

This function is a small but complete WSGI application that returns a text page containing the message “Hello world!” and a list of the key/value pairs provided in the *environ* parameter. It’s useful for verifying that a WSGI server (such as `wsgiref.simple_server`) is able to run a simple WSGI application correctly.

**class** `wsgiref.simple_server.WSGIServer` (*server\_address*, *RequestHandlerClass*)

Create a `WSGIServer` instance. *server\_address* should be a (*host*, *port*) tuple, and *RequestHandlerClass* should be the subclass of `BaseHTTPServer.BaseHTTPRequestHandler` that will be used to process requests.

You do not normally need to call this constructor, as the `make_server()` function can handle all the details for you.

`WSGIServer` is a subclass of `BaseHTTPServer.HTTPServer`, so all of its methods (such as `serve_forever()` and `handle_request()`) are available. `WSGIServer` also provides these WSGI-specific methods:

**set\_app** (*application*)

Sets the callable *application* as the WSGI application that will receive requests.

**get\_app** ()

Returns the currently-set application callable.

Normally, however, you do not need to use these additional methods, as `set_app()` is normally called by `make_server()`, and the `get_app()` exists mainly for the benefit of request handler instances.

**class** `wsgiref.simple_server.WSGIRequestHandler` (*request*, *client\_address*, *server*)

Create an HTTP handler for the given *request* (i.e. a socket), *client\_address* (a (*host*, *port*) tuple), and *server* (`WSGIServer` instance).

You do not need to create instances of this class directly; they are automatically created as needed by `WSGIServer` objects. You can, however, subclass this class and supply it as a *handler\_class* to the `make_server()` function. Some possibly relevant methods for overriding in subclasses:

**get\_environ** ()

Returns a dictionary containing the WSGI environment for a request. The default implementation copies the contents of the `WSGIServer` object’s `base_environ` dictionary attribute and then adds various headers derived from the HTTP request. Each call to this method should return a new dictionary containing all of the relevant CGI environment variables as specified in

**PEP 333.**

**get\_stderr** ()

Return the object that should be used as the `wsgi.errors` stream. The default implementation just returns `sys.stderr`.

**handle()**

Process the HTTP request. The default implementation creates a handler instance using a `wsgiref.handlers` class to implement the actual WSGI application interface.

**20.4.4 wsgiref.validate — WSGI conformance checker**

When creating new WSGI application objects, frameworks, servers, or middleware, it can be useful to validate the new code's conformance using `wsgiref.validate`. This module provides a function that creates WSGI application objects that validate communications between a WSGI server or gateway and a WSGI application object, to check both sides for protocol conformance.

Note that this utility does not guarantee complete **PEP 333** compliance; an absence of errors from this module does not necessarily mean that errors do not exist. However, if this module does produce an error, then it is virtually certain that either the server or application is not 100% compliant.

This module is based on the `paste.lint` module from Ian Bicking's "Python Paste" library.

`wsgiref.validate.validator` (*application*)

Wrap *application* and return a new WSGI application object. The returned application will forward all requests to the original *application*, and will check that both the *application* and the server invoking it are conforming to the WSGI specification and to RFC 2616.

Any detected nonconformance results in an `AssertionError` being raised; note, however, that how these errors are handled is server-dependent. For example, `wsgiref.simple_server` and other servers based on `wsgiref.handlers` (that don't override the error handling methods to do something else) will simply output a message that an error has occurred, and dump the traceback to `sys.stderr` or some other error stream.

This wrapper may also generate output using the `warnings` module to indicate behaviors that are questionable but which may not actually be prohibited by **PEP 333**. Unless they are suppressed using Python command-line options or the `warnings` API, any such warnings will be written to `sys.stderr` (*not* `wsgi.errors`, unless they happen to be the same object).

Example usage:

```
from wsgiref.validate import validator
from wsgiref.simple_server import make_server

# Our callable object which is intentionally not compliant to the
# standard, so the validator is going to break
def simple_app(environ, start_response):
    status = '200 OK' # HTTP Status
    headers = [('Content-type', 'text/plain')] # HTTP Headers
    start_response(status, headers)

    # This is going to break because we need to return a list, and
    # the validator is going to inform us
    return "Hello World"

# This is the application wrapped in a validator
validator_app = validator(simple_app)

httpd = make_server('', 8000, validator_app)
print "Listening on port 8000...."
httpd.serve_forever()
```

## 20.4.5 wsgiref.handlers – server/gateway base classes

This module provides base handler classes for implementing WSGI servers and gateways. These base classes handle most of the work of communicating with a WSGI application, as long as they are given a CGI-like environment, along with input, output, and error streams.

### class wsgiref.handlers.CGIHandler

CGI-based invocation via `sys.stdin`, `sys.stdout`, `sys.stderr` and `os.environ`. This is useful when you have a WSGI application and want to run it as a CGI script. Simply invoke `CGIHandler().run(app)`, where `app` is the WSGI application object you wish to invoke.

This class is a subclass of `BaseCGIHandler` that sets `wsgi.run_once` to `true`, `wsgi.multithread` to `false`, and `wsgi.multiprocess` to `true`, and always uses `sys` and `os` to obtain the necessary CGI streams and environment.

### class wsgiref.handlers.BaseCGIHandler(*stdin, stdout, stderr, environ, multithread=True, multiprocess=False*)

Similar to `CGIHandler`, but instead of using the `sys` and `os` modules, the CGI environment and I/O streams are specified explicitly. The `multithread` and `multiprocess` values are used to set the `wsgi.multithread` and `wsgi.multiprocess` flags for any applications run by the handler instance.

This class is a subclass of `SimpleHandler` intended for use with software other than HTTP “origin servers”. If you are writing a gateway protocol implementation (such as CGI, FastCGI, SCGI, etc.) that uses a `Status:` header to send an HTTP status, you probably want to subclass this instead of `SimpleHandler`.

### class wsgiref.handlers.SimpleHandler(*stdin, stdout, stderr, environ, multithread=True, multiprocess=False*)

Similar to `BaseCGIHandler`, but designed for use with HTTP origin servers. If you are writing an HTTP server implementation, you will probably want to subclass this instead of `BaseCGIHandler`.

This class is a subclass of `BaseHandler`. It overrides the `__init__()`, `get_stdin()`, `get_stderr()`, `add_cgi_vars()`, `_write()`, and `_flush()` methods to support explicitly setting the environment and streams via the constructor. The supplied environment and streams are stored in the `stdin`, `stdout`, `stderr`, and `environ` attributes.

### class wsgiref.handlers.BaseHandler

This is an abstract base class for running WSGI applications. Each instance will handle a single HTTP request, although in principle you could create a subclass that was reusable for multiple requests.

`BaseHandler` instances have only one method intended for external use:

#### run(*app*)

Run the specified WSGI application, *app*.

All of the other `BaseHandler` methods are invoked by this method in the process of running the application, and thus exist primarily to allow customizing the process.

The following methods MUST be overridden in a subclass:

#### `_write(data)`

Buffer the string *data* for transmission to the client. It’s okay if this method actually transmits the data; `BaseHandler` just separates write and flush operations for greater efficiency when the underlying system actually has such a distinction.

#### `_flush()`

Force buffered data to be transmitted to the client. It’s okay if this method is a no-op (i.e., if `_write()` actually sends the data).

#### `get_stdin()`

Return an input stream object suitable for use as the `wsgi.input` of the request currently being processed.

**get\_stderr()**

Return an output stream object suitable for use as the `wsgi.errors` of the request currently being processed.

**add\_cgi\_vars()**

Insert CGI variables for the current request into the `environ` attribute.

Here are some other methods and attributes you may wish to override. This list is only a summary, however, and does not include every method that can be overridden. You should consult the docstrings and source code for additional information before attempting to create a customized `BaseHandler` subclass.

Attributes and methods for customizing the WSGI environment:

**wsgi\_multithread**

The value to be used for the `wsgi.multithread` environment variable. It defaults to true in `BaseHandler`, but may have a different default (or be set by the constructor) in the other subclasses.

**wsgi\_multiprocess**

The value to be used for the `wsgi.multiprocess` environment variable. It defaults to true in `BaseHandler`, but may have a different default (or be set by the constructor) in the other subclasses.

**wsgi\_run\_once**

The value to be used for the `wsgi.run_once` environment variable. It defaults to false in `BaseHandler`, but `CGIHandler` sets it to true by default.

**os\_environ**

The default environment variables to be included in every request's WSGI environment. By default, this is a copy of `os.environ` at the time that `wsgiref.handlers` was imported, but subclasses can either create their own at the class or instance level. Note that the dictionary should be considered read-only, since the default value is shared between multiple classes and instances.

**server\_software**

If the `origin_server` attribute is set, this attribute's value is used to set the default `SERVER_SOFTWARE` WSGI environment variable, and also to set a default `Server:` header in HTTP responses. It is ignored for handlers (such as `BaseCGIHandler` and `CGIHandler`) that are not HTTP origin servers.

**get\_scheme()**

Return the URL scheme being used for the current request. The default implementation uses the `guess_scheme()` function from `wsgiref.util` to guess whether the scheme should be "http" or "https", based on the current request's `environ` variables.

**setup\_environ()**

Set the `environ` attribute to a fully-populated WSGI environment. The default implementation uses all of the above methods and attributes, plus the `get_stdin()`, `get_stderr()`, and `add_cgi_vars()` methods and the `wsgi_file_wrapper` attribute. It also inserts a `SERVER_SOFTWARE` key if not present, as long as the `origin_server` attribute is a true value and the `server_software` attribute is set.

Methods and attributes for customizing exception handling:

**log\_exception(exc\_info)**

Log the `exc_info` tuple in the server log. `exc_info` is a `(type, value, traceback)` tuple. The default implementation simply writes the traceback to the request's `wsgi.errors` stream and flushes it. Subclasses can override this method to change the format or retarget the output, mail the traceback to an administrator, or whatever other action may be deemed suitable.

**traceback\_limit**

The maximum number of frames to include in tracebacks output by the default `log_exception()` method. If `None`, all frames are included.

**error\_output** (*environ*, *start\_response*)

This method is a WSGI application to generate an error page for the user. It is only invoked if an error occurs before headers are sent to the client.

This method can access the current error information using `sys.exc_info()`, and should pass that information to *start\_response* when calling it (as described in the “Error Handling” section of [PEP 333](#)).

The default implementation just uses the `error_status`, `error_headers`, and `error_body` attributes to generate an output page. Subclasses can override this to produce more dynamic error output.

Note, however, that it’s not recommended from a security perspective to spit out diagnostics to any old user; ideally, you should have to do something special to enable diagnostic output, which is why the default implementation doesn’t include any.

**error\_status**

The HTTP status used for error responses. This should be a status string as defined in [PEP 333](#); it defaults to a 500 code and message.

**error\_headers**

The HTTP headers used for error responses. This should be a list of WSGI response headers ((*name*, *value*) tuples), as described in [PEP 333](#). The default list just sets the content type to `text/plain`.

**error\_body**

The error response body. This should be an HTTP response body string. It defaults to the plain text, “A server error occurred. Please contact the administrator.”

Methods and attributes for [PEP 333](#)’s “Optional Platform-Specific File Handling” feature:

**wsgi\_file\_wrapper**

A `wsgi.file_wrapper` factory, or `None`. The default value of this attribute is the `FileWrapper` class from `wsgiref.util`.

**sendfile()**

Override to implement platform-specific file transmission. This method is called only if the application’s return value is an instance of the class specified by the `wsgi_file_wrapper` attribute. It should return a true value if it was able to successfully transmit the file, so that the default transmission code will not be executed. The default implementation of this method just returns a false value.

Miscellaneous methods and attributes:

**origin\_server**

This attribute should be set to a true value if the handler’s `_write()` and `_flush()` are being used to communicate directly to the client, rather than via a CGI-like gateway protocol that wants the HTTP status in a special `Status:` header.

This attribute’s default value is true in `BaseHandler`, but false in `BaseCGIHandler` and `CGIHandler`.

**http\_version**

If `origin_server` is true, this string attribute is used to set the HTTP version of the response set to the client. It defaults to `"1.0"`.

## 20.4.6 Examples

This is a working “Hello World” WSGI application:

```
from wsgiref.simple_server import make_server
```

```
# Every WSGI application must have an application object - a callable  
# object that accepts two arguments. For that purpose, we're going to
```

```

# use a function (note that you're not limited to a function, you can
# use a class for example). The first argument passed to the function
# is a dictionary containing CGI-style environment variables and the
# second variable is the callable object (see PEP 333).
def hello_world_app(environ, start_response):
    status = '200 OK' # HTTP Status
    headers = [('Content-type', 'text/plain')] # HTTP Headers
    start_response(status, headers)

    # The returned object is going to be printed
    return ["Hello World"]

httpd = make_server('', 8000, hello_world_app)
print "Serving on port 8000..."

# Serve until process is killed
httpd.serve_forever()

```

## 20.5 urllib — Open arbitrary resources by URL

**Note:** The `urllib` module has been split into parts and renamed in Python 3 to `urllib.request`, `urllib.parse`, and `urllib.error`. The `2to3` tool will automatically adapt imports when converting your sources to Python 3. Also note that the `urllib.urlopen()` function has been removed in Python 3 in favor of `urllib2.urlopen()`.

This module provides a high-level interface for fetching data across the World Wide Web. In particular, the `urlopen()` function is similar to the built-in function `open()`, but accepts Universal Resource Locators (URLs) instead of filenames. Some restrictions apply — it can only open URLs for reading, and no seek operations are available.

**Warning:** When opening HTTPS URLs, it does not attempt to validate the server certificate. Use at your own risk!

### 20.5.1 High-level interface

`urllib.urlopen(url[, data[, proxies]])`

Open a network object denoted by a URL for reading. If the URL does not have a scheme identifier, or if it has `file:` as its scheme identifier, this opens a local file (without *universal newlines*); otherwise it opens a socket to a server somewhere on the network. If the connection cannot be made the `IOError` exception is raised. If all went well, a file-like object is returned. This supports the following methods: `read()`, `readline()`, `readlines()`, `fileno()`, `close()`, `info()`, `getcode()` and `geturl()`. It also has proper support for the *iterator* protocol. One caveat: the `read()` method, if the size argument is omitted or negative, may not read until the end of the data stream; there is no good way to determine that the entire stream from a socket has been read in the general case.

Except for the `info()`, `getcode()` and `geturl()` methods, these methods have the same interface as for file objects — see section *File Objects* in this manual. (It is not a built-in file object, however, so it can't be used at those few places where a true built-in file object is required.)

The `info()` method returns an instance of the class `mimetypes.Message` containing meta-information associated with the URL. When the method is HTTP, these headers are those returned by the server at the

head of the retrieved HTML page (including Content-Length and Content-Type). When the method is FTP, a Content-Length header will be present if (as is now usual) the server passed back a file length in response to the FTP retrieval request. A Content-Type header will be present if the MIME type can be guessed. When the method is local-file, returned headers will include a Date representing the file's last-modified time, a Content-Length giving file size, and a Content-Type containing a guess at the file's type. See also the description of the `mimertools` module.

The `geturl()` method returns the real URL of the page. In some cases, the HTTP server redirects a client to another URL. The `urlopen()` function handles this transparently, but in some cases the caller needs to know which URL the client was redirected to. The `geturl()` method can be used to get at this redirected URL.

The `getcode()` method returns the HTTP status code that was sent with the response, or `None` if the URL is no HTTP URL.

If the `url` uses the `http:` scheme identifier, the optional `data` argument may be given to specify a POST request (normally the request type is GET). The `data` argument must be in standard `application/x-www-form-urlencoded` format; see the `urlencode()` function below.

The `urlopen()` function works transparently with proxies which do not require authentication. In a Unix or Windows environment, set the

`http_proxy`, or `ftp_proxy` environment variables to a URL that identifies the proxy server before starting the Python interpreter. For example (the `' % '` is the command prompt):

```
% http_proxy="http://www.someproxy.com:3128"
% export http_proxy
% python
...

```

The `no_proxy` environment variable can be used to specify hosts which shouldn't be reached via proxy; if set, it should be a comma-separated list of hostname suffixes, optionally with `:port` appended, for example `cern.ch, ncsa.uiuc.edu, some.host:8080`.

In a Windows environment, if no proxy environment variables are set, proxy settings are obtained from the registry's Internet Settings section.

In a Mac OS X environment, `urlopen()` will retrieve proxy information from the OS X System Configuration Framework, which can be managed with Network System Preferences panel.

Alternatively, the optional `proxies` argument may be used to explicitly specify proxies. It must be a dictionary mapping scheme names to proxy URLs, where an empty dictionary causes no proxies to be used, and `None` (the default value) causes environmental proxy settings to be used as discussed above. For example:

```
# Use http://www.someproxy.com:3128 for http proxying
proxies = {'http': 'http://www.someproxy.com:3128'}
filehandle = urllib.urlopen(some_url, proxies=proxies)
# Don't use any proxies
filehandle = urllib.urlopen(some_url, proxies={})
# Use proxies from environment - both versions are equivalent
filehandle = urllib.urlopen(some_url, proxies=None)
filehandle = urllib.urlopen(some_url)

```

Proxies which require authentication for use are not currently supported; this is considered an implementation limitation. Changed in version 2.3: Added the `proxies` support. Changed in version 2.6: Added `getcode()` to returned object and support for the

`no_proxy` environment variable. Deprecated since version 2.6: The `urlopen()` function has been removed in Python 3 in favor of `urllib2.urlopen()`.

`urllib.urlretrieve(url[, filename[, reporthook[, data]]])`

Copy a network object denoted by a URL to a local file, if necessary. If the URL points to a local file, or a valid cached copy of the object exists, the object is not copied. Return a tuple (`filename`, `headers`) where `filename` is the local file name under which the object can be found, and `headers` is whatever the `info()` method of the object returned by `urlopen()` returned (for a remote object, possibly cached). Exceptions are the same as for `urlopen()`.

The second argument, if present, specifies the file location to copy to (if absent, the location will be a tempfile with a generated name). The third argument, if present, is a hook function that will be called once on establishment of the network connection and once after each block read thereafter. The hook will be passed three arguments; a count of blocks transferred so far, a block size in bytes, and the total size of the file. The third argument may be `-1` on older FTP servers which do not return a file size in response to a retrieval request.

If the `url` uses the `http:` scheme identifier, the optional `data` argument may be given to specify a POST request (normally the request type is GET). The `data` argument must in standard `application/x-www-form-urlencoded` format; see the `urlencode()` function below. Changed in version 2.5: `urlretrieve()` will raise `ContentTooShortError` when it detects that the amount of data available was less than the expected amount (which is the size reported by a `Content-Length` header). This can occur, for example, when the download is interrupted. The `Content-Length` is treated as a lower bound: if there's more data to read, `urlretrieve()` reads more data, but if less data is available, it raises the exception.

You can still retrieve the downloaded data in this case, it is stored in the `content` attribute of the exception instance.

If no `Content-Length` header was supplied, `urlretrieve()` can not check the size of the data it has downloaded, and just returns it. In this case you just have to assume that the download was successful.

`urllib._urlopener`

The public functions `urlopen()` and `urlretrieve()` create an instance of the `FancyURLopener` class and use it to perform their requested actions. To override this functionality, programmers can create a subclass of `URLopener` or `FancyURLopener`, then assign an instance of that class to the `urllib._urlopener` variable before calling the desired function. For example, applications may want to specify a different `User-Agent` header than `URLopener` defines. This can be accomplished with the following code:

```
import urllib

class AppURLopener(urllib.FancyURLopener):
    version = "App/1.7"

urllib._urlopener = AppURLopener()
```

`urllib.urlcleanup()`

Clear the cache that may have been built up by previous calls to `urlretrieve()`.

## 20.5.2 Utility functions

`urllib.quote(string[, safe])`

Replace special characters in `string` using the `%xx` escape. Letters, digits, and the characters `'_.-'` are never quoted. By default, this function is intended for quoting the path section of the URL. The optional `safe` parameter specifies additional characters that should not be quoted — its default value is `'/'`.

Example: `quote('/~connolly/')` yields `'/%7econnolly/'`.

`urllib.quote_plus(string[, safe])`

Like `quote()`, but also replaces spaces by plus signs, as required for quoting HTML form values when building

up a query string to go into a URL. Plus signs in the original string are escaped unless they are included in *safe*. It also does not have *safe* default to `'/'`.

`urllib.unquote(string)`

Replace `%xx` escapes by their single-character equivalent.

Example: `unquote('/%7Econnolly/')` yields `'/~connolly/'`.

`urllib.unquote_plus(string)`

Like `unquote()`, but also replaces plus signs by spaces, as required for unquoting HTML form values.

`urllib.urlencode(query[, doseq])`

Convert a mapping object or a sequence of two-element tuples to a “percent-encoded” string, suitable to pass to `urlopen()` above as the optional *data* argument. This is useful to pass a dictionary of form fields to a POST request. The resulting string is a series of `key=value` pairs separated by `'&'` characters, where both *key* and *value* are quoted using `quote_plus()` above. When a sequence of two-element tuples is used as the *query* argument, the first element of each tuple is a key and the second is a value. The value element in itself can be a sequence and in that case, if the optional parameter *doseq* is evaluates to *True*, individual `key=value` pairs separated by `'&'` are generated for each element of the value sequence for the key. The order of parameters in the encoded string will match the order of parameter tuples in the sequence. The `urlparse` module provides the functions `parse_qs()` and `parse_qs1()` which are used to parse query strings into Python data structures.

`urllib.pathname2url(path)`

Convert the pathname *path* from the local syntax for a path to the form used in the path component of a URL. This does not produce a complete URL. The return value will already be quoted using the `quote()` function.

`urllib.url2pathname(path)`

Convert the path component *path* from an percent-encoded URL to the local syntax for a path. This does not accept a complete URL. This function uses `unquote()` to decode *path*.

`urllib.getproxies()`

This helper function returns a dictionary of scheme to proxy server URL mappings. It scans the environment for variables named `<scheme>_proxy`, in case insensitive way, for all operating systems first, and when it cannot find it, looks for proxy information from Mac OSX System Configuration for Mac OS X and Windows Systems Registry for Windows.

### 20.5.3 URL Opener objects

`class urllib.URLopener([proxies[, **x509]])`

Base class for opening and reading URLs. Unless you need to support opening objects using schemes other than `http:`, `ftp:`, or `file:`, you probably want to use `FancyURLopener`.

By default, the `URLopener` class sends a *User-Agent* header of `urllib/VVV`, where *VVV* is the `urllib` version number. Applications can define their own *User-Agent* header by subclassing `URLopener` or `FancyURLopener` and setting the class attribute `version` to an appropriate string value in the subclass definition.

The optional *proxies* parameter should be a dictionary mapping scheme names to proxy URLs, where an empty dictionary turns proxies off completely. Its default value is `None`, in which case environmental proxy settings will be used if present, as discussed in the definition of `urlopen()`, above.

Additional keyword parameters, collected in *x509*, may be used for authentication of the client when using the `https:` scheme. The keywords *key\_file* and *cert\_file* are supported to provide an SSL key and certificate; both are needed to support client authentication.

`URLopener` objects will raise an `IOError` exception if the server returns an error code.

**open** (*fullurl* [, *data* ])

Open *fullurl* using the appropriate protocol. This method sets up cache and proxy information, then calls the appropriate open method with its input arguments. If the scheme is not recognized, `open_unknown()` is called. The *data* argument has the same meaning as the *data* argument of `urlopen()`.

**open\_unknown** (*fullurl* [, *data* ])

Overridable interface to open unknown URL types.

**retrieve** (*url* [, *filename* [, *reporhook* [, *data* ] ] ])

Retrieves the contents of *url* and places it in *filename*. The return value is a tuple consisting of a local filename and either a `mimetools.Message` object containing the response headers (for remote URLs) or `None` (for local URLs). The caller must then open and read the contents of *filename*. If *filename* is not given and the URL refers to a local file, the input filename is returned. If the URL is non-local and *filename* is not given, the filename is the output of `tempfile.mktemp()` with a suffix that matches the suffix of the last path component of the input URL. If *reporhook* is given, it must be a function accepting three numeric parameters. It will be called after each chunk of data is read from the network. *reporhook* is ignored for local URLs.

If the *url* uses the `http:` scheme identifier, the optional *data* argument may be given to specify a POST request (normally the request type is GET). The *data* argument must in standard `application/x-www-form-urlencoded` format; see the `urlencode()` function below.

**version**

Variable that specifies the user agent of the opener object. To get `urllib` to tell servers that it is a particular user agent, set this in a subclass as a class variable or in the constructor before calling the base constructor.

**class** `urllib.FancyURLopener` (...)

`FancyURLopener` subclasses `URLopener` providing default handling for the following HTTP response codes: 301, 302, 303, 307 and 401. For the 30x response codes listed above, the `Location` header is used to fetch the actual URL. For 401 response codes (authentication required), basic HTTP authentication is performed. For the 30x response codes, recursion is bounded by the value of the `maxtries` attribute, which defaults to 10.

For all other response codes, the method `http_error_default()` is called which you can override in subclasses to handle the error appropriately.

---

**Note:** According to the letter of **RFC 2616**, 301 and 302 responses to POST requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a GET, and `urllib` reproduces this behaviour.

---

The parameters to the constructor are the same as those for `URLopener`.

---

**Note:**

When performing basic authentication, a `FancyURLopener` instance calls its `prompt_user_passwd()` method. The default implementation asks the users for the required information on the controlling terminal. A subclass may override this method to support more appropriate behavior if needed.

The `FancyURLopener` class offers one additional method that should be overloaded to provide the appropriate behavior:

**prompt\_user\_passwd** (*host*, *realm*)

Return information needed to authenticate the user at the given host in the specified security realm. The return value should be a tuple, (user, password), which can be used for basic authentication.

The implementation prompts for this information on the terminal; an application should override this method to use an appropriate interaction model in the local environment.

---

**exception** `urllib.ContentTooShortError` (*msg* [, *content* ])

This exception is raised when the `urlretrieve()` function detects that the amount of the downloaded data is less than the expected amount (given by the *Content-Length* header). The `content` attribute stores the downloaded (and supposedly truncated) data. New in version 2.5.

### 20.5.4 urllib Restrictions

- Currently, only the following protocols are supported: HTTP, (versions 0.9 and 1.0), FTP, and local files.
- The caching feature of `urlretrieve()` has been disabled until I find the time to hack proper processing of Expiration time headers.
- There should be a function to query whether a particular URL is in the cache.
- For backward compatibility, if a URL appears to point to a local file but the file can't be opened, the URL is re-interpreted using the FTP protocol. This can sometimes cause confusing error messages.
- The `urlopen()` and `urlretrieve()` functions can cause arbitrarily long delays while waiting for a network connection to be set up. This means that it is difficult to build an interactive Web client using these functions without using threads.
- The data returned by `urlopen()` or `urlretrieve()` is the raw data returned by the server. This may be binary data (such as an image), plain text or (for example) HTML. The HTTP protocol provides type information in the reply header, which can be inspected by looking at the *Content-Type* header. If the returned data is HTML, you can use the module `htmllib` to parse it.
- The code handling the FTP protocol cannot differentiate between a file and a directory. This can lead to unexpected behavior when attempting to read a URL that points to a file that is not accessible. If the URL ends in a `/`, it is assumed to refer to a directory and will be handled accordingly. But if an attempt to read a file leads to a 550 error (meaning the URL cannot be found or is not accessible, often for permission reasons), then the path is treated as a directory in order to handle the case when a directory is specified by a URL but the trailing `/` has been left off. This can cause misleading results when you try to fetch a file whose read permissions make it inaccessible; the FTP code will try to read it, fail with a 550 error, and then perform a directory listing for the unreadable file. If fine-grained control is needed, consider using the `ftplib` module, subclassing `FancyURLopener`, or changing `_urloper` to meet your needs.
- This module does not support the use of proxies which require authentication. This may be implemented in the future.
- Although the `urllib` module contains (undocumented) routines to parse and unparse URL strings, the recommended interface for URL manipulation is in module `urlparse`.

### 20.5.5 Examples

Here is an example session that uses the GET method to retrieve a URL containing parameters:

```
>>> import urllib
>>> params = urllib.urlencode({'spam': 1, 'eggs': 2, 'bacon': 0})
```

```
>>> f = urllib.urlopen("http://www.musi-cal.com/cgi-bin/query?%s" % params)
>>> print f.read()
```

The following example uses the POST method instead:

```
>>> import urllib
>>> params = urllib.urlencode({'spam': 1, 'eggs': 2, 'bacon': 0})
>>> f = urllib.urlopen("http://www.musi-cal.com/cgi-bin/query", params)
>>> print f.read()
```

The following example uses an explicitly specified HTTP proxy, overriding environment settings:

```
>>> import urllib
>>> proxies = {'http': 'http://proxy.example.com:8080/'}
>>> opener = urllib.FancyURLopener(proxies)
>>> f = opener.open("http://www.python.org")
>>> f.read()
```

The following example uses no proxies at all, overriding environment settings:

```
>>> import urllib
>>> opener = urllib.FancyURLopener({})
>>> f = opener.open("http://www.python.org/")
>>> f.read()
```

## 20.6 urllib2 — extensible library for opening URLs

**Note:** The `urllib2` module has been split across several modules in Python 3 named `urllib.request` and `urllib.error`. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

The `urllib2` module defines functions and classes which help in opening URLs (mostly HTTP) in a complex world — basic and digest authentication, redirections, cookies and more.

The `urllib2` module defines the following functions:

`urllib2.urlopen(url[, data][, timeout])`

Open the URL *url*, which can be either a string or a `Request` object.

**Warning:** HTTPS requests do not do any verification of the server's certificate.

*data* may be a string specifying additional data to send to the server, or `None` if no such data is needed. Currently HTTP requests are the only ones that use *data*; the HTTP request will be a POST instead of a GET when the *data* parameter is provided. *data* should be a buffer in the standard `application/x-www-form-urlencoded` format. The `urllib.urlencode()` function takes a mapping or sequence of 2-tuples and returns a string in this format. `urllib2` module sends HTTP/1.1 requests with `Connection:close` header included.

The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). This actually only works for HTTP, HTTPS and FTP connections.

This function returns a file-like object with two additional methods:

- `geturl()` — return the URL of the resource retrieved, commonly used to determine if a redirect was followed
- `info()` — return the meta-information of the page, such as headers, in the form of an `mimertools.Message` instance (see [Quick Reference to HTTP Headers](#))

Raises `URLError` on errors.

Note that `None` may be returned if no handler handles the request (though the default installed global `OpenerDirector` uses `UnknownHandler` to ensure this never happens).

In addition, default installed `ProxyHandler` makes sure the requests are handled through the proxy when they are set. Changed in version 2.6: `timeout` was added.

`urllib2.install_opener(opener)`

Install an `OpenerDirector` instance as the default global opener. Installing an opener is only necessary if you want `urlopen` to use that opener; otherwise, simply call `OpenerDirector.open()` instead of `urlopen()`. The code does not check for a real `OpenerDirector`, and any class with the appropriate interface will work.

`urllib2.build_opener([handler, ...])`

Return an `OpenerDirector` instance, which chains the handlers in the order given. `handlers` can be either instances of `BaseHandler`, or subclasses of `BaseHandler` (in which case it must be possible to call the constructor without any parameters). Instances of the following classes will be in front of the `handlers`, unless the `handlers` contain them, instances of them or subclasses of them: `ProxyHandler`, `UnknownHandler`, `HTTPHandler`, `HTTPDefaultErrorHandler`, `HTTPRedirectHandler`, `FTPHandler`, `FileHandler`, `HTTPErrorProcessor`.

If the Python installation has SSL support (i.e., if the `ssl` module can be imported), `HTTPSHandler` will also be added.

Beginning in Python 2.3, a `BaseHandler` subclass may also change its `handler_order` attribute to modify its position in the handlers list.

The following exceptions are raised as appropriate:

**exception** `urllib2.URLError`

The handlers raise this exception (or derived exceptions) when they run into a problem. It is a subclass of `IOError`.

**reason**

The reason for this error. It can be a message string or another exception instance (`socket.error` for remote URLs, `OSError` for local URLs).

**exception** `urllib2.HTTPError`

Though being an exception (a subclass of `URLError`), an `HTTPError` can also function as a non-exceptional file-like return value (the same thing that `urlopen()` returns). This is useful when handling exotic HTTP errors, such as requests for authentication.

**code**

An HTTP status code as defined in RFC 2616. This numeric value corresponds to a value found in the dictionary of codes as found in `BaseHTTPServer.BaseHTTPRequestHandler.responses`.

The following classes are provided:

**class** `urllib2.Request(url[, data][, headers][, origin_req_host][, unverifiable])`

This class is an abstraction of a URL request.

`url` should be a string containing a valid URL.

`data` may be a string specifying additional data to send to the server, or `None` if no such data is needed. Currently HTTP requests are the only ones that use `data`; the HTTP request will be a POST instead of a GET when the `data` parameter is provided. `data` should be a buffer in the standard `application/x-www-form-urlencoded` format. The `urllib.urlencode()` function takes a mapping or sequence of 2-tuples and returns a string in this format.

`headers` should be a dictionary, and will be treated as if `add_header()` was called with each key and value as arguments. This is often used to “spoof” the `User-Agent` header, which is used by a browser to identify itself – some HTTP servers only allow requests coming from common browsers as opposed to scripts. For example,

Mozilla Firefox may identify itself as "Mozilla/5.0 (X11; U; Linux i686) Gecko/20071127 Firefox/2.0.0.11", while `urllib2`'s default user agent string is "Python-urllib/2.6" (on Python 2.6).

The final two arguments are only of interest for correct handling of third-party HTTP cookies:

`origin_req_host` should be the request-host of the origin transaction, as defined by [RFC 2965](#). It defaults to `cookieilib.request_host(self)`. This is the host name or IP address of the original request that was initiated by the user. For example, if the request is for an image in an HTML document, this should be the request-host of the request for the page containing the image.

`unverifiable` should indicate whether the request is unverifiable, as defined by RFC 2965. It defaults to False. An unverifiable request is one whose URL the user did not have the option to approve. For example, if the request is for an image in an HTML document, and the user had no option to approve the automatic fetching of the image, this should be true.

**class** `urllib2.OpenerDirector`

The `OpenerDirector` class opens URLs via `BaseHandlers` chained together. It manages the chaining of handlers, and recovery from errors.

**class** `urllib2.BaseHandler`

This is the base class for all registered handlers — and handles only the simple mechanics of registration.

**class** `urllib2.HTTPDefaultErrorHandler`

A class which defines a default handler for HTTP error responses; all responses are turned into `HTTPError` exceptions.

**class** `urllib2.HTTPRedirectHandler`

A class to handle redirections.

**class** `urllib2.HTTPCookieProcessor` (`[cookiejar]`)

A class to handle HTTP Cookies.

**class** `urllib2.ProxyHandler` (`[proxies]`)

Cause requests to go through a proxy. If `proxies` is given, it must be a dictionary mapping protocol names to URLs of proxies. The default is to read the list of proxies from the environment variables

`<protocol>_proxy`. If no proxy environment variables are set, in a Windows environment, proxy settings are obtained from the registry's Internet Settings section and in a Mac OS X environment, proxy information is retrieved from the OS X System Configuration Framework.

To disable autodetected proxy pass an empty dictionary.

**class** `urllib2.HTTPPasswordMgr`

Keep a database of `(realm, uri) -> (user, password)` mappings.

**class** `urllib2.HTTPPasswordMgrWithDefaultRealm`

Keep a database of `(realm, uri) -> (user, password)` mappings. A realm of `None` is considered a catch-all realm, which is searched if no other realm fits.

**class** `urllib2.AbstractBasicAuthHandler` (`[password_mgr]`)

This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section [HTTPPasswordMgr Objects](#) for information on the interface that must be supported.

**class** `urllib2.HTTPBasicAuthHandler` (`[password_mgr]`)

Handle authentication with the remote host. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section [HTTPPasswordMgr Objects](#) for information on the interface that must be supported.

**class** `urllib2.ProxyBasicAuthHandler` (`[password_mgr]`)

Handle authentication with the proxy. `password_mgr`, if given, should be something that is compatible with

`HTTPPasswordMgr`; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

**class** `urllib2.AbstractDigestAuthHandler` (`[password_mgr]`)

This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

**class** `urllib2.HTTPDigestAuthHandler` (`[password_mgr]`)

Handle authentication with the remote host. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

**class** `urllib2.ProxyDigestAuthHandler` (`[password_mgr]`)

Handle authentication with the proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

**class** `urllib2.HTTPHandler`

A class to handle opening of HTTP URLs.

**class** `urllib2.HTTPSHandler`

A class to handle opening of HTTPS URLs.

**class** `urllib2.FileHandler`

Open local files.

**class** `urllib2.FTPHandler`

Open FTP URLs.

**class** `urllib2.CacheFTPHandler`

Open FTP URLs, keeping a cache of open FTP connections to minimize delays.

**class** `urllib2.UnknownHandler`

A catch-all class to handle unknown URLs.

**class** `urllib2.HTTPErrorProcessor`

Process HTTP error responses.

## 20.6.1 Request Objects

The following methods describe all of `Request`'s public interface, and so all must be overridden in subclasses.

`Request.add_data` (`data`)

Set the `Request` data to `data`. This is ignored by all handlers except HTTP handlers — and there it should be a byte string, and will change the request to be POST rather than GET.

`Request.get_method` ()

Return a string indicating the HTTP request method. This is only meaningful for HTTP requests, and currently always returns 'GET' or 'POST'.

`Request.has_data` ()

Return whether the instance has a non-None data.

`Request.get_data` ()

Return the instance's data.

`Request.add_header` (`key`, `val`)

Add another header to the request. Headers are currently ignored by all handlers except HTTP handlers, where they are added to the list of headers sent to the server. Note that there cannot be more than one header with the same name, and later calls will overwrite previous calls in case the `key` collides. Currently, this is no loss of

HTTP functionality, since all headers which have meaning when used more than once have a (header-specific) way of gaining the same functionality using only one header.

`Request.add_unredirected_header` (*key*, *header*)

Add a header that will not be added to a redirected request. New in version 2.4.

`Request.has_header` (*header*)

Return whether the instance has the named header (checks both regular and unredirected). New in version 2.4.

`Request.get_full_url` ()

Return the URL given in the constructor.

`Request.get_type` ()

Return the type of the URL — also known as the scheme.

`Request.get_host` ()

Return the host to which a connection will be made.

`Request.get_selector` ()

Return the selector — the part of the URL that is sent to the server.

`Request.get_header` (*header\_name*, *default=None*)

Return the value of the given header. If the header is not present, return the default value.

`Request.header_items` ()

Return a list of tuples (*header\_name*, *header\_value*) of the Request headers.

`Request.set_proxy` (*host*, *type*)

Prepare the request by connecting to a proxy server. The *host* and *type* will replace those of the instance, and the instance's selector will be the original URL given in the constructor.

`Request.get_origin_req_host` ()

Return the request-host of the origin transaction, as defined by [RFC 2965](#). See the documentation for the `Request` constructor.

`Request.is_unverifiable` ()

Return whether the request is unverifiable, as defined by RFC 2965. See the documentation for the `Request` constructor.

## 20.6.2 OpenerDirector Objects

`OpenerDirector` instances have the following methods:

`OpenerDirector.add_handler` (*handler*)

*handler* should be an instance of `BaseHandler`. The following methods are searched, and added to the possible chains (note that HTTP errors are a special case).

- `'protocol_open'` — signal that the handler knows how to open *protocol* URLs.
- `'http_error_type'` — signal that the handler knows how to handle HTTP errors with HTTP error code *type*.
- `'protocol_error'` — signal that the handler knows how to handle errors from (non-http) *protocol*.
- `'protocol_request'` — signal that the handler knows how to pre-process *protocol* requests.
- `'protocol_response'` — signal that the handler knows how to post-process *protocol* responses.

`OpenerDirector.open` (*url*[, *data*][, *timeout*])

Open the given *url* (which can be a request object or a string), optionally passing the given *data*. Arguments, return values and exceptions raised are the same as those of `urlopen()` (which simply calls the `open()` method on the currently installed global `OpenerDirector`). The optional *timeout* parameter specifies a

timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). The timeout feature actually works only for HTTP, HTTPS and FTP connections). Changed in version 2.6: *timeout* was added.

`OpenerDirector.error(proto[, arg[, ...]])`

Handle an error of the given protocol. This will call the registered error handlers for the given protocol with the given arguments (which are protocol specific). The HTTP protocol is a special case which uses the HTTP response code to determine the specific error handler; refer to the `http_error_*()` methods of the handler classes.

Return values and exceptions raised are the same as those of `urlopen()`.

`OpenerDirector` objects open URLs in three stages:

The order in which these methods are called within each stage is determined by sorting the handler instances.

1. Every handler with a method named like 'protocol\_request' has that method called to pre-process the request.
2. Handlers with a method named like 'protocol\_open' are called to handle the request. This stage ends when a handler either returns a non-`None` value (ie. a response), or raises an exception (usually `URLError`). Exceptions are allowed to propagate.

In fact, the above algorithm is first tried for methods named `default_open()`. If all such methods return `None`, the algorithm is repeated for methods named like 'protocol\_open'. If all such methods return `None`, the algorithm is repeated for methods named `unknown_open()`.

Note that the implementation of these methods may involve calls of the parent `OpenerDirector` instance's `open()` and `error()` methods.

3. Every handler with a method named like 'protocol\_response' has that method called to post-process the response.

### 20.6.3 BaseHandler Objects

`BaseHandler` objects provide a couple of methods that are directly useful, and others that are meant to be used by derived classes. These are intended for direct use:

`BaseHandler.add_parent(director)`

Add a director as parent.

`BaseHandler.close()`

Remove any parents.

The following attributes and methods should only be used by classes derived from `BaseHandler`.

---

**Note:** The convention has been adopted that subclasses defining `protocol_request()` or `protocol_response()` methods are named `*Processor`; all others are named `*Handler`.

---

`BaseHandler.parent`

A valid `OpenerDirector`, which can be used to open using a different protocol, or handle errors.

`BaseHandler.default_open(req)`

This method is *not* defined in `BaseHandler`, but subclasses should define it if they want to catch all URLs.

This method, if implemented, will be called by the parent `OpenerDirector`. It should return a file-like object as described in the return value of the `open()` of `OpenerDirector`, or `None`. It should raise `URLError`, unless a truly exceptional thing happens (for example, `MemoryError` should not be mapped to `URLError`).

This method will be called before any protocol-specific open method.

`BaseHandler.protocol_open` (*req*)  
 (“protocol” is to be replaced by the protocol name.)

This method is *not* defined in `BaseHandler`, but subclasses should define it if they want to handle URLs with the given *protocol*.

This method, if defined, will be called by the parent `OpenerDirector`. Return values should be the same as for `default_open()`.

`BaseHandler.unknown_open` (*req*)

This method is *not* defined in `BaseHandler`, but subclasses should define it if they want to catch all URLs with no specific registered handler to open it.

This method, if implemented, will be called by the parent `OpenerDirector`. Return values should be the same as for `default_open()`.

`BaseHandler.http_error_default` (*req, fp, code, msg, hdrs*)

This method is *not* defined in `BaseHandler`, but subclasses should override it if they intend to provide a catch-all for otherwise unhandled HTTP errors. It will be called automatically by the `OpenerDirector` getting the error, and should not normally be called in other circumstances.

*req* will be a `Request` object, *fp* will be a file-like object with the HTTP error body, *code* will be the three-digit code of the error, *msg* will be the user-visible explanation of the code and *hdrs* will be a mapping object with the headers of the error.

Return values and exceptions raised should be the same as those of `urlopen()`.

`BaseHandler.http_error_nnn` (*req, fp, code, msg, hdrs*)

*nnn* should be a three-digit HTTP error code. This method is also not defined in `BaseHandler`, but will be called, if it exists, on an instance of a subclass, when an HTTP error with code *nnn* occurs.

Subclasses should override this method to handle specific HTTP errors.

Arguments, return values and exceptions raised should be the same as for `http_error_default()`.

`BaseHandler.protocol_request` (*req*)  
 (“protocol” is to be replaced by the protocol name.)

This method is *not* defined in `BaseHandler`, but subclasses should define it if they want to pre-process requests of the given *protocol*.

This method, if defined, will be called by the parent `OpenerDirector`. *req* will be a `Request` object. The return value should be a `Request` object.

`BaseHandler.protocol_response` (*req, response*)  
 (“protocol” is to be replaced by the protocol name.)

This method is *not* defined in `BaseHandler`, but subclasses should define it if they want to post-process responses of the given *protocol*.

This method, if defined, will be called by the parent `OpenerDirector`. *req* will be a `Request` object. *response* will be an object implementing the same interface as the return value of `urlopen()`. The return value should implement the same interface as the return value of `urlopen()`.

## 20.6.4 HTTPRedirectHandler Objects

---

**Note:** Some HTTP redirections require action from this module’s client code. If this is the case, `HTTPError` is raised. See [RFC 2616](#) for details of the precise meanings of the various redirection codes.

---

`HTTPRedirectHandler.redirect_request` (*req, fp, code, msg, hdrs, newurl*)

Return a `Request` or `None` in response to a redirect. This is called by the default implementations of the `http_error_30*` (`code`) methods when a redirection is received from the server. If a redirection should take place, return a new `Request` to allow `http_error_30*` (`code`) to perform the redirect to *newurl*. Otherwise, raise `HTTPError` if no other handler should try to handle this URL, or return `None` if you can't but another handler might.

---

**Note:** The default implementation of this method does not strictly follow [RFC 2616](#), which says that 301 and 302 responses to POST requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a GET, and the default implementation reproduces this behavior.

---

`HTTPRedirectHandler.http_error_301` (*req, fp, code, msg, hdrs*)

Redirect to the `Location:` or `URI:` URL. This method is called by the parent `OpenerDirector` when getting an HTTP 'moved permanently' response.

`HTTPRedirectHandler.http_error_302` (*req, fp, code, msg, hdrs*)

The same as `http_error_301` (`code`), but called for the 'found' response.

`HTTPRedirectHandler.http_error_303` (*req, fp, code, msg, hdrs*)

The same as `http_error_301` (`code`), but called for the 'see other' response.

`HTTPRedirectHandler.http_error_307` (*req, fp, code, msg, hdrs*)

The same as `http_error_301` (`code`), but called for the 'temporary redirect' response.

### 20.6.5 HTTPCookieProcessor Objects

New in version 2.4. `HTTPCookieProcessor` instances have one attribute:

`HTTPCookieProcessor.cookiejar`

The `cookielib.CookieJar` in which cookies are stored.

### 20.6.6 ProxyHandler Objects

`ProxyHandler.protocol_open` (*request*)

("protocol" is to be replaced by the protocol name.)

The `ProxyHandler` will have a method 'protocol\_open' for every *protocol* which has a proxy in the `proxies` dictionary given in the constructor. The method will modify requests to go through the proxy, by calling `request.set_proxy()`, and call the next handler in the chain to actually execute the protocol.

### 20.6.7 HTTPPasswordMgr Objects

These methods are available on `HTTPPasswordMgr` and `HTTPPasswordMgrWithDefaultRealm` objects.

`HTTPPasswordMgr.add_password` (*realm, uri, user, passwd*)

*uri* can be either a single URI, or a sequence of URIs. *realm*, *user* and *passwd* must be strings. This causes (*user*, *passwd*) to be used as authentication tokens when authentication for *realm* and a super-URI of any of the given URIs is given.

`HTTPPasswordMgr.find_user_password` (*realm, authuri*)

Get user/password for given realm and URI, if any. This method will return (`None`, `None`) if there is no matching user/password.

For `HTTPPasswordMgrWithDefaultRealm` objects, the realm `None` will be searched if the given *realm* has no matching user/password.

## 20.6.8 AbstractBasicAuthHandler Objects

`AbstractBasicAuthHandler.http_error_auth_reged` (*authreq, host, req, headers*)

Handle an authentication request by getting a user/password pair, and re-trying the request. *authreq* should be the name of the header where the information about the realm is included in the request, *host* specifies the URL and path to authenticate for, *req* should be the (failed) `Request` object, and *headers* should be the error headers.

*host* is either an authority (e.g. "python.org") or a URL containing an authority component (e.g. "http://python.org/"). In either case, the authority must not contain a userinfo component (so, "python.org" and "python.org:80" are fine, "joe:password@python.org" is not).

## 20.6.9 HTTPBasicAuthHandler Objects

`HTTPBasicAuthHandler.http_error_401` (*req, fp, code, msg, hdrs*)

Retry the request with authentication information, if available.

## 20.6.10 ProxyBasicAuthHandler Objects

`ProxyBasicAuthHandler.http_error_407` (*req, fp, code, msg, hdrs*)

Retry the request with authentication information, if available.

## 20.6.11 AbstractDigestAuthHandler Objects

`AbstractDigestAuthHandler.http_error_auth_reged` (*authreq, host, req, headers*)

*authreq* should be the name of the header where the information about the realm is included in the request, *host* should be the host to authenticate to, *req* should be the (failed) `Request` object, and *headers* should be the error headers.

## 20.6.12 HTTPDigestAuthHandler Objects

`HTTPDigestAuthHandler.http_error_401` (*req, fp, code, msg, hdrs*)

Retry the request with authentication information, if available.

## 20.6.13 ProxyDigestAuthHandler Objects

`ProxyDigestAuthHandler.http_error_407` (*req, fp, code, msg, hdrs*)

Retry the request with authentication information, if available.

## 20.6.14 HTTPHandler Objects

`HTTPHandler.http_open` (*req*)

Send an HTTP request, which can be either GET or POST, depending on `req.has_data()`.

## 20.6.15 HTTPSHandler Objects

`HTTPSHandler.https_open(req)`

Send an HTTPS request, which can be either GET or POST, depending on `req.has_data()`.

## 20.6.16 FileHandler Objects

`FileHandler.file_open(req)`

Open the file locally, if there is no host name, or the host name is `'localhost'`. Change the protocol to `ftp` otherwise, and retry opening it using `parent`.

## 20.6.17 FTPHandler Objects

`FTPHandler.ftp_open(req)`

Open the FTP file indicated by `req`. The login is always done with empty username and password.

## 20.6.18 CacheFTPHandler Objects

`CacheFTPHandler` objects are `FTPHandler` objects with the following additional methods:

`CacheFTPHandler.setTimeout(t)`

Set timeout of connections to `t` seconds.

`CacheFTPHandler.setMaxConns(m)`

Set maximum number of cached connections to `m`.

## 20.6.19 UnknownHandler Objects

`UnknownHandler.unknown_open()`

Raise a `URLError` exception.

## 20.6.20 HTTPErrorProcessor Objects

New in version 2.4.

`HTTPErrorProcessor.http_response()`

Process HTTP error responses.

For 200 error codes, the response object is returned immediately.

For non-200 error codes, this simply passes the job on to the `'protocol_error_code'` handler methods, via `OpenerDirector.error()`. Eventually, `urllib2.HTTPDefaultErrorHandler` will raise an `HTTPError` if no other handler handles the error.

`HTTPErrorProcessor.https_response()`

Process HTTPS error responses.

The behavior is same as `http_response()`.

## 20.6.21 Examples

This example gets the python.org main page and displays the first 100 bytes of it:

```
>>> import urllib2
>>> f = urllib2.urlopen('http://www.python.org/')
>>> print f.read(100)
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
<?xml-stylesheet href="./css/ht2html
```

Here we are sending a data-stream to the stdin of a CGI and reading the data it returns to us. Note that this example will only work when the Python installation supports SSL.

```
>>> import urllib2
>>> req = urllib2.Request(url='https://localhost/cgi-bin/test.cgi',
...                       data='This data is passed to stdin of the CGI')
>>> f = urllib2.urlopen(req)
>>> print f.read()
Got Data: "This data is passed to stdin of the CGI"
```

The code for the sample CGI used in the above example is:

```
#!/usr/bin/env python
import sys
data = sys.stdin.read()
print 'Content-type: text-plain\n\nGot Data: "%s"' % data
```

Use of Basic HTTP Authentication:

```
import urllib2
# Create an OpenerDirector with support for Basic HTTP Authentication...
auth_handler = urllib2.HTTPBasicAuthHandler()
auth_handler.add_password(realm='PDQ Application',
                          uri='https://mahler:8092/site-updates.py',
                          user='klem',
                          passwd='kadidd!ehopper')
opener = urllib2.build_opener(auth_handler)
# ...and install it globally so it can be used with urlopen.
urllib2.install_opener(opener)
urllib2.urlopen('http://www.example.com/login.html')
```

`build_opener()` provides many handlers by default, including a `ProxyHandler`. By default, `ProxyHandler` uses the environment variables named `<scheme>_proxy`, where `<scheme>` is the URL scheme involved. For example, the `http_proxy` environment variable is read to obtain the HTTP proxy's URL.

This example replaces the default `ProxyHandler` with one that uses programmatically-supplied proxy URLs, and adds proxy authorization support with `ProxyBasicAuthHandler`.

```
proxy_handler = urllib2.ProxyHandler({'http': 'http://www.example.com:3128/'})
proxy_auth_handler = urllib2.ProxyBasicAuthHandler()
proxy_auth_handler.add_password('realm', 'host', 'username', 'password')

opener = urllib2.build_opener(proxy_handler, proxy_auth_handler)
# This time, rather than install the OpenerDirector, we use it directly:
opener.open('http://www.example.com/login.html')
```

Adding HTTP headers:

Use the `headers` argument to the `Request` constructor, or:

```
import urllib2
req = urllib2.Request('http://www.example.com/')
req.add_header('Referer', 'http://www.python.org/')
r = urllib2.urlopen(req)
```

`OpenerDirector` automatically adds a *User-Agent* header to every `Request`. To change this:

```
import urllib2
opener = urllib2.build_opener()
opener.addheaders = [('User-agent', 'Mozilla/5.0')]
opener.open('http://www.example.com/')
```

Also, remember that a few standard headers (*Content-Length*, *Content-Type* and *Host*) are added when the `Request` is passed to `urlopen()` (or `OpenerDirector.open()`).

## 20.7 urllib — HTTP protocol client

---

**Note:** The `urllib` module has been renamed to `http.client` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

**Source code:** [Lib/urllib.py](#)

---

This module defines classes which implement the client side of the HTTP and HTTPS protocols. It is normally not used directly — the module `urllib` uses it to handle URLs that use HTTP and HTTPS.

---

**Note:** HTTPS support is only available if the `socket` module was compiled with SSL support.

---

**Note:** The public interface for this module changed substantially in Python 2.0. The `HTTP` class is retained only for backward compatibility with 1.5.2. It should not be used in new code. Refer to the online docstrings for usage.

---

The module provides the following classes:

**class** `urllib.HTTPConnection`(*host*[, *port*[, *strict*[, *timeout*[, *source\_address* ] ] ] ])

An `HTTPConnection` instance represents one transaction with an HTTP server. It should be instantiated passing it a host and optional port number. If no port number is passed, the port is extracted from the host string if it has the form `host:port`, else the default HTTP port (80) is used. When `True`, the optional parameter *strict* (which defaults to a false value) causes `BadStatusLine` to be raised if the status line can't be parsed as a valid HTTP/1.0 or 1.1 status line. If the optional *timeout* parameter is given, blocking operations (like connection attempts) will timeout after that many seconds (if it is not given, the global default timeout setting is used). The optional *source\_address* parameter may be a tuple of a (host, port) to use as the source address the HTTP connection is made from.

For example, the following calls all create instances that connect to the server at the same host and port:

```
>>> h1 = urllib.HTTPConnection('www.cwi.nl')
>>> h2 = urllib.HTTPConnection('www.cwi.nl:80')
>>> h3 = urllib.HTTPConnection('www.cwi.nl', 80)
>>> h3 = urllib.HTTPConnection('www.cwi.nl', 80, timeout=10)
```

New in version 2.0.Changed in version 2.6: *timeout* was added.Changed in version 2.7: *source\_address* was added.

**class** `httplib.HTTPSConnection` (*host*[, *port*[, *key\_file*[, *cert\_file*[, *strict*[, *timeout*[, *source\_address* ] ] ] ] ] )

A subclass of `HTTPConnection` that uses SSL for communication with secure servers. Default port is 443. *key\_file* is the name of a PEM formatted file that contains your private key. *cert\_file* is a PEM formatted certificate chain file.

**Warning:** This does not do any verification of the server's certificate.

New in version 2.0. Changed in version 2.6: *timeout* was added. Changed in version 2.7: *source\_address* was added.

**class** `httplib.HTTPResponse` (*sock*, *debuglevel=0*, *strict=0*)

Class whose instances are returned upon successful connection. Not instantiated directly by user. New in version 2.0.

**class** `httplib.HTTPMessage`

An `HTTPMessage` instance is used to hold the headers from an HTTP response. It is implemented using the `mimetypes.Message` class and provides utility functions to deal with HTTP Headers. It is not directly instantiated by the users.

The following exceptions are raised as appropriate:

**exception** `httplib.HTTPException`

The base class of the other exceptions in this module. It is a subclass of `Exception`. New in version 2.0.

**exception** `httplib.NotConnected`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.InvalidURL`

A subclass of `HTTPException`, raised if a port is given and is either non-numeric or empty. New in version 2.3.

**exception** `httplib.UnknownProtocol`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.UnknownTransferEncoding`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.UnimplementedFileMode`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.IncompleteRead`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.ImproperConnectionState`

A subclass of `HTTPException`. New in version 2.0.

**exception** `httplib.CannotSendRequest`

A subclass of `ImproperConnectionState`. New in version 2.0.

**exception** `httplib.CannotSendHeader`

A subclass of `ImproperConnectionState`. New in version 2.0.

**exception** `httplib.ResponseNotReady`

A subclass of `ImproperConnectionState`. New in version 2.0.

**exception** `httplib.BadStatusLine`

A subclass of `HTTPException`. Raised if a server responds with a HTTP status code that we don't understand. New in version 2.0.

The constants defined in this module are:

`httplib.HTTP_PORT`

The default port for the HTTP protocol (always 80).

`httplib.HTTPS_PORT`

The default port for the HTTPS protocol (always 443).

and also the following constants for integer status codes:

Constant	Value	Definition
CONTINUE	100	HTTP/1.1, RFC 2616, Section 10.1.1
SWITCHING_PROTOCOLS	101	HTTP/1.1, RFC 2616, Section 10.1.2
PROCESSING	102	WEBDAV, RFC 2518, Section 10.1
OK	200	HTTP/1.1, RFC 2616, Section 10.2.1
CREATED	201	HTTP/1.1, RFC 2616, Section 10.2.2
ACCEPTED	202	HTTP/1.1, RFC 2616, Section 10.2.3
NON_AUTHORITATIVE_INFORMATION	203	HTTP/1.1, RFC 2616, Section 10.2.4
NO_CONTENT	204	HTTP/1.1, RFC 2616, Section 10.2.5
RESET_CONTENT	205	HTTP/1.1, RFC 2616, Section 10.2.6
PARTIAL_CONTENT	206	HTTP/1.1, RFC 2616, Section 10.2.7
MULTI_STATUS	207	WEBDAV RFC 2518, Section 10.2
IM_USED	226	Delta encoding in HTTP, <b>RFC 3229</b> , Section 10.4.1
MULTIPLE_CHOICES	300	HTTP/1.1, RFC 2616, Section 10.3.1
MOVED_PERMANENTLY	301	HTTP/1.1, RFC 2616, Section 10.3.2
FOUND	302	HTTP/1.1, RFC 2616, Section 10.3.3
SEE_OTHER	303	HTTP/1.1, RFC 2616, Section 10.3.4
NOT_MODIFIED	304	HTTP/1.1, RFC 2616, Section 10.3.5
USE_PROXY	305	HTTP/1.1, RFC 2616, Section 10.3.6
TEMPORARY_REDIRECT	307	HTTP/1.1, RFC 2616, Section 10.3.8
BAD_REQUEST	400	HTTP/1.1, RFC 2616, Section 10.4.1
UNAUTHORIZED	401	HTTP/1.1, RFC 2616, Section 10.4.2
PAYMENT_REQUIRED	402	HTTP/1.1, RFC 2616, Section 10.4.3
FORBIDDEN	403	HTTP/1.1, RFC 2616, Section 10.4.4
NOT_FOUND	404	HTTP/1.1, RFC 2616, Section 10.4.5
METHOD_NOT_ALLOWED	405	HTTP/1.1, RFC 2616, Section 10.4.6
NOT_ACCEPTABLE	406	HTTP/1.1, RFC 2616, Section 10.4.7
PROXY_AUTHENTICATION_REQUIRED	407	HTTP/1.1, RFC 2616, Section 10.4.8
REQUEST_TIMEOUT	408	HTTP/1.1, RFC 2616, Section 10.4.9
CONFLICT	409	HTTP/1.1, RFC 2616, Section 10.4.10
GONE	410	HTTP/1.1, RFC 2616, Section 10.4.11
LENGTH_REQUIRED	411	HTTP/1.1, RFC 2616, Section 10.4.12
PRECONDITION_FAILED	412	HTTP/1.1, RFC 2616, Section 10.4.13
REQUEST_ENTITY_TOO_LARGE	413	HTTP/1.1, RFC 2616, Section 10.4.14
REQUEST_URI_TOO_LONG	414	HTTP/1.1, RFC 2616, Section 10.4.15
UNSUPPORTED_MEDIA_TYPE	415	HTTP/1.1, RFC 2616, Section 10.4.16
REQUESTED_RANGE_NOT_SATISFIABLE	416	HTTP/1.1, RFC 2616, Section 10.4.17
EXPECTATION_FAILED	417	HTTP/1.1, RFC 2616, Section 10.4.18
UNPROCESSABLE_ENTITY	422	WEBDAV, RFC 2518, Section 10.3
LOCKED	423	WEBDAV RFC 2518, Section 10.4
FAILED_DEPENDENCY	424	WEBDAV, RFC 2518, Section 10.5
UPGRADE_REQUIRED	426	HTTP Upgrade to TLS, <b>RFC 2817</b> , Section 6
INTERNAL_SERVER_ERROR	500	HTTP/1.1, RFC 2616, Section 10.5.1
NOT_IMPLEMENTED	501	HTTP/1.1, RFC 2616, Section 10.5.2
BAD_GATEWAY	502	HTTP/1.1 RFC 2616, Section 10.5.3
SERVICE_UNAVAILABLE	503	HTTP/1.1, RFC 2616, Section 10.5.4

Continued on next page

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GATEWAY_TIMEOUT	504	HTTP/1.1 RFC 2616, Section 10.5.5
HTTP_VERSION_NOT_SUPPORTED	505	HTTP/1.1, RFC 2616, Section 10.5.6
INSUFFICIENT_STORAGE	507	WEBDAV, RFC 2518, Section 10.6
NOT_EXTENDED	510	An HTTP Extension Framework, RFC 2774, Section 7

**httplib.responses**

This dictionary maps the HTTP 1.1 status codes to the W3C names.

Example: `httplib.responses[httplib.NOT_FOUND]` is 'Not Found'. New in version 2.5.

**20.7.1 HTTPConnection Objects**

`HTTPConnection` instances have the following methods:

`HTTPConnection.request` (*method*, *url* [, *body* [, *headers* ] ])

This will send a request to the server using the HTTP request method *method* and the selector *url*. If the *body* argument is present, it should be a string of data to send after the headers are finished. Alternatively, it may be an open file object, in which case the contents of the file is sent; this file object should support `fileno()` and `read()` methods. The header Content-Length is automatically set to the correct value. The *headers* argument should be a mapping of extra HTTP headers to send with the request. Changed in version 2.6: *body* can be a file object.

`HTTPConnection.getresponse` ()

Should be called after a request is sent to get the response from the server. Returns an `HTTPResponse` instance.

---

**Note:** Note that you must have read the whole response before you can send a new request to the server.

---

`HTTPConnection.set_debuglevel` (*level*)

Set the debugging level (the amount of debugging output printed). The default debug level is 0, meaning no debugging output is printed.

`HTTPConnection.set_tunnel` (*host*, *port*=None, *headers*=None)

Set the host and the port for HTTP Connect Tunnelling. Normally used when it is required to do HTTPS Connection through a proxy server.

The *headers* argument should be a mapping of extra HTTP headers to send with the CONNECT request. New in version 2.7.

`HTTPConnection.connect` ()

Connect to the server specified when the object was created.

`HTTPConnection.close` ()

Close the connection to the server.

As an alternative to using the `request()` method described above, you can also send your request step by step, by using the four functions below.

`HTTPConnection.putrequest` (*request*, *selector* [, *skip\_host* [, *skip\_accept\_encoding* ] ])

This should be the first call after the connection to the server has been made. It sends a line to the server consisting of the *request* string, the *selector* string, and the HTTP version (HTTP/1.1). To disable automatic sending of Host: or Accept-Encoding: headers (for example to accept additional content encodings), specify *skip\_host* or *skip\_accept\_encoding* with non-False values. Changed in version 2.4: *skip\_accept\_encoding* argument added.

`HTTPConnection.putheader` (*header*, *argument* [, ... ])

Send an RFC 822-style header to the server. It sends a line to the server consisting of the header, a colon and a

space, and the first argument. If more arguments are given, continuation lines are sent, each consisting of a tab and an argument.

`HTTPConnection.endheaders` (*message\_body=None*)

Send a blank line to the server, signalling the end of the headers. The optional *message\_body* argument can be used to pass a message body associated with the request. The message body will be sent in the same packet as the message headers if it is string, otherwise it is sent in a separate packet. Changed in version 2.7: *message\_body* was added.

`HTTPConnection.send` (*data*)

Send data to the server. This should be used directly only after the `endheaders()` method has been called and before `getresponse()` is called.

### 20.7.2 HTTPResponse Objects

`HTTPResponse` instances have the following methods and attributes:

`HTTPResponse.read` (*[amt]*)

Reads and returns the response body, or up to the next *amt* bytes.

`HTTPResponse.getheader` (*name* [*, default*])

Get the contents of the header *name*, or *default* if there is no matching header.

`HTTPResponse.getheaders` ()

Return a list of (header, value) tuples. New in version 2.4.

`HTTPResponse.fileno` ()

Returns the `fileno` of the underlying socket.

`HTTPResponse.msg`

A `mimetools.Message` instance containing the response headers.

`HTTPResponse.version`

HTTP protocol version used by server. 10 for HTTP/1.0, 11 for HTTP/1.1.

`HTTPResponse.status`

Status code returned by server.

`HTTPResponse.reason`

Reason phrase returned by server.

### 20.7.3 Examples

Here is an example session that uses the GET method:

```
>>> import httplib
>>> conn = httplib.HTTPConnection("www.python.org")
>>> conn.request("GET", "/index.html")
>>> r1 = conn.getresponse()
>>> print r1.status, r1.reason
200 OK
>>> data1 = r1.read()
>>> conn.request("GET", "/parrot.spam")
>>> r2 = conn.getresponse()
>>> print r2.status, r2.reason
404 Not Found
>>> data2 = r2.read()
>>> conn.close()
```

Here is an example session that uses the HEAD method. Note that the HEAD method never returns any data.

```
>>> import httplib
>>> conn = httplib.HTTPConnection("www.python.org")
>>> conn.request("HEAD", "/index.html")
>>> res = conn.getresponse()
>>> print res.status, res.reason
200 OK
>>> data = res.read()
>>> print len(data)
0
>>> data == ''
True
```

Here is an example session that shows how to POST requests:

```
>>> import httplib, urllib
>>> params = urllib.urlencode({'@number': 12524, '@type': 'issue', '@action': 'show'})
>>> headers = {"Content-type": "application/x-www-form-urlencoded",
...           "Accept": "text/plain"}
>>> conn = httplib.HTTPConnection("bugs.python.org")
>>> conn.request("POST", "", params, headers)
>>> response = conn.getresponse()
>>> print response.status, response.reason
302 Found
>>> data = response.read()
>>> data
'Redirecting to <a href="http://bugs.python.org/issue12524">http://bugs.python.org/issue12524'
>>> conn.close()
```

## 20.8 ftplib — FTP protocol client

**Source code:** `Lib/ftplib.py`

This module defines the class `FTP` and a few related items. The `FTP` class implements the client side of the FTP protocol. You can use this to write Python programs that perform a variety of automated FTP jobs, such as mirroring other ftp servers. It is also used by the module `urllib` to handle URLs that use FTP. For more information on FTP (File Transfer Protocol), see Internet [RFC 959](#).

Here's a sample session using the `ftplib` module:

```
>>> from ftplib import FTP
>>> ftp = FTP('ftp.cwi.nl')      # connect to host, default port
>>> ftp.login()                 # user anonymous, passwd anonymous@
>>> ftp.retrlines('LIST')       # list directory contents
total 24418
drwxrwsr-x   5 ftp-usr  pdmaint      1536 Mar 20 09:48 .
dr-xr-srwt 105 ftp-usr  pdmaint      1536 Mar 21 14:32 ..
-rw-r--r--   1 ftp-usr  pdmaint      5305 Mar 20 09:48 INDEX
.
.
.
>>> ftp.retrbinary('RETR README', open('README', 'wb').write)
```

```
'226 Transfer complete.'
>>> ftp.quit()
```

The module defines the following items:

**class** `ftplib.FTP` (`[host[, user[, passwd[, acct[, timeout ]]]]]`)

Return a new instance of the `FTP` class. When `host` is given, the method call `connect(host)` is made. When `user` is given, additionally the method call `login(user, passwd, acct)` is made (where `passwd` and `acct` default to the empty string when not given). The optional `timeout` parameter specifies a timeout in seconds for blocking operations like the connection attempt (if is not specified, the global default timeout setting will be used). Changed in version 2.6: `timeout` was added.

**class** `ftplib.FTP_TLS` (`[host[, user[, passwd[, acct[, keyfile[, certfile[, timeout ]]]]]]]`)

A `FTP` subclass which adds TLS support to FTP as described in

**RFC 4217**. Connect as usual to port 21 implicitly securing the FTP control connection before authenticating. Securing the data connection requires the user to explicitly ask for it by calling the `prot_p()` method. `keyfile` and `certfile` are optional – they can contain a PEM formatted private key and certificate chain file name for the SSL connection. New in version 2.7. Here's a sample session using the `FTP_TLS` class:

```
>>> from ftplib import FTP_TLS
>>> ftps = FTP_TLS('ftp.python.org')
>>> ftps.login() # login anonymously before securing control channel
>>> ftps.prot_p() # switch to secure data connection
>>> ftps.retrlines('LIST') # list directory content securely
total 9
drwxr-xr-x  8 root    wheel   1024 Jan  3  1994 .
drwxr-xr-x  8 root    wheel   1024 Jan  3  1994 ..
drwxr-xr-x  2 root    wheel   1024 Jan  3  1994 bin
drwxr-xr-x  2 root    wheel   1024 Jan  3  1994 etc
d-wxrwxr-x  2 ftp     wheel   1024 Sep  5 13:43 incoming
drwxr-xr-x  2 root    wheel   1024 Nov 17  1993 lib
drwxr-xr-x  6 1094    wheel   1024 Sep 13 19:07 pub
drwxr-xr-x  3 root    wheel   1024 Jan  3  1994 usr
-rw-r--r--  1 root    root     312 Aug  1  1994 welcome.msg
'226 Transfer complete.'
>>> ftps.quit()
>>>
```

**exception** `ftplib.error_reply`

Exception raised when an unexpected reply is received from the server.

**exception** `ftplib.error_temp`

Exception raised when an error code signifying a temporary error (response codes in the range 400–499) is received.

**exception** `ftplib.error_perm`

Exception raised when an error code signifying a permanent error (response codes in the range 500–599) is received.

**exception** `ftplib.error_proto`

Exception raised when a reply is received from the server that does not fit the response specifications of the File Transfer Protocol, i.e. begin with a digit in the range 1–5.

`ftplib.all_errors`

The set of all exceptions (as a tuple) that methods of `FTP` instances may raise as a result of problems with the FTP connection (as opposed to programming errors made by the caller). This set includes the four exceptions listed above as well as `socket.error` and `IOError`.

**See Also:**

**Module `netrc`** Parser for the `.netrc` file format. The file `.netrc` is typically used by FTP clients to load user authentication information before prompting the user.

The file `Tools/scripts/ftpmirror.py` in the Python source distribution is a script that can mirror FTP sites, or portions thereof, using the `ftplib` module. It can be used as an extended example that applies this module.

## 20.8.1 FTP Objects

Several methods are available in two flavors: one for handling text files and another for binary files. These are named for the command which is used followed by `lines` for the text version or `binary` for the binary version.

FTP instances have the following methods:

FTP.**set\_debuglevel** (*level*)

Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

FTP.**connect** (*host*[, *port*[, *timeout* ] ])

Connect to the given host and port. The default port number is 21, as specified by the FTP protocol specification. It is rarely needed to specify a different port number. This function should be called only once for each instance; it should not be called at all if a host was given when the instance was created. All other methods can only be used after a connection has been made.

The optional *timeout* parameter specifies a timeout in seconds for the connection attempt. If no *timeout* is passed, the global default timeout setting will be used. Changed in version 2.6: *timeout* was added.

FTP.**getwelcome** ()

Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

FTP.**login** ([*user*[, *passwd*[, *acct* ] ] ])

Log in as the given *user*. The *passwd* and *acct* parameters are optional and default to the empty string. If no *user* is specified, it defaults to 'anonymous'. If *user* is 'anonymous', the default *passwd* is 'anonymous@'. This function should be called only once for each instance, after a connection has been established; it should not be called at all if a host and user were given when the instance was created. Most FTP commands are only allowed after the client has logged in. The *acct* parameter supplies "accounting information"; few systems implement this.

FTP.**abort** ()

Abort a file transfer that is in progress. Using this does not always work, but it's worth a try.

FTP.**sendcmd** (*command*)

Send a simple command string to the server and return the response string.

FTP.**voidcmd** (*command*)

Send a simple command string to the server and handle the response. Return nothing if a response code corresponding to success (codes in the range 200–299) is received. Raise `error_reply` otherwise.

FTP.**retrbinary** (*command*, *callback*[, *maxblocksize*[, *rest* ] ])

Retrieve a file in binary transfer mode. *command* should be an appropriate RETR command: 'RETR *filename*'. The *callback* function is called for each block of data received, with a single string argument giving the data block. The optional *maxblocksize* argument specifies the maximum chunk size to read on the low-level socket object created to do the actual transfer (which will also be the largest size of the data blocks passed to *callback*). A reasonable default is chosen. *rest* means the same thing as in the `transfercmd()` method.

FTP.**retrlines** (*command*[, *callback* ])

Retrieve a file or directory listing in ASCII transfer mode. *command* should be an appropriate RETR command (see `retrbinary()`) or a command such as LIST, NLST or MLSD (usually just the string 'LIST'). LIST retrieves a list of files and information about those files. NLST retrieves a list of file names. On some servers, MLSD retrieves a machine readable list of files and information about those files. The *callback* function is called for each line with a string argument containing the line with the trailing CRLF stripped. The default *callback* prints the line to `sys.stdout`.

FTP.**set\_pasv** (*boolean*)

Enable “passive” mode if *boolean* is true, other disable passive mode. (In Python 2.0 and before, passive mode was off by default; in Python 2.1 and later, it is on by default.)

FTP.**storbinary** (*command*, *file*[, *blocksize*, *callback*, *rest* ])

Store a file in binary transfer mode. *command* should be an appropriate STOR command: "STOR filename". *file* is an open file object which is read until EOF using its `read()` method in blocks of size *blocksize* to provide the data to be stored. The *blocksize* argument defaults to 8192. *callback* is an optional single parameter callable that is called on each block of data after it is sent. *rest* means the same thing as in the `transfercmd()` method. Changed in version 2.1: default for *blocksize* added. Changed in version 2.6: *callback* parameter added. Changed in version 2.7: *rest* parameter added.

FTP.**storlines** (*command*, *file*[, *callback* ])

Store a file in ASCII transfer mode. *command* should be an appropriate STOR command (see `storbinary()`). Lines are read until EOF from the open file object *file* using its `readline()` method to provide the data to be stored. *callback* is an optional single parameter callable that is called on each line after it is sent. Changed in version 2.6: *callback* parameter added.

FTP.**transfercmd** (*cmd*[, *rest* ])

Initiate a transfer over the data connection. If the transfer is active, send a EPRT or PORT command and the transfer command specified by *cmd*, and accept the connection. If the server is passive, send a EPSV or PASV command, connect to it, and start the transfer command. Either way, return the socket for the connection.

If optional *rest* is given, a REST command is sent to the server, passing *rest* as an argument. *rest* is usually a byte offset into the requested file, telling the server to restart sending the file’s bytes at the requested offset, skipping over the initial bytes. Note however that RFC 959 requires only that *rest* be a string containing characters in the printable range from ASCII code 33 to ASCII code 126. The `transfercmd()` method, therefore, converts *rest* to a string, but no check is performed on the string’s contents. If the server does not recognize the REST command, an `error_reply` exception will be raised. If this happens, simply call `transfercmd()` without a *rest* argument.

FTP.**ntransfercmd** (*cmd*[, *rest* ])

Like `transfercmd()`, but returns a tuple of the data connection and the expected size of the data. If the expected size could not be computed, `None` will be returned as the expected size. *cmd* and *rest* means the same thing as in `transfercmd()`.

FTP.**nlst** (*argument*[, ... ])

Return a list of file names as returned by the NLST command. The optional *argument* is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the NLST command.

FTP.**dir** (*argument*[, ... ])

Produce a directory listing as returned by the LIST command, printing it to standard output. The optional *argument* is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the LIST command. If the last argument is a function, it is used as a *callback* function as for `retrlines()`; the default prints to `sys.stdout`. This method returns `None`.

FTP.**rename** (*fromname*, *toname*)

Rename file *fromname* on the server to *toname*.

- `FTP.delete(filename)`  
Remove the file named *filename* from the server. If successful, returns the text of the response, otherwise raises `error_perm` on permission errors or `error_reply` on other errors.
- `FTP.cwd(pathname)`  
Set the current directory on the server.
- `FTP.mkd(pathname)`  
Create a new directory on the server.
- `FTP.pwd()`  
Return the pathname of the current directory on the server.
- `FTP.rmd(dirname)`  
Remove the directory named *dirname* on the server.
- `FTP.size(filename)`  
Request the size of the file named *filename* on the server. On success, the size of the file is returned as an integer, otherwise `None` is returned. Note that the `SIZE` command is not standardized, but is supported by many common server implementations.
- `FTP.quit()`  
Send a `QUIT` command to the server and close the connection. This is the “polite” way to close a connection, but it may raise an exception if the server responds with an error to the `QUIT` command. This implies a call to the `close()` method which renders the `FTP` instance useless for subsequent calls (see below).
- `FTP.close()`  
Close the connection unilaterally. This should not be applied to an already closed connection such as after a successful call to `quit()`. After this call the `FTP` instance should not be used any more (after a call to `close()` or `quit()` you cannot reopen the connection by issuing another `login()` method).

## 20.8.2 FTP\_TLS Objects

`FTP_TLS` class inherits from `FTP`, defining these additional objects:

- `FTP_TLS.ssl_version`  
The SSL version to use (defaults to `TLSv1`).
- `FTP_TLS.auth()`  
Set up secure control connection by using TLS or SSL, depending on what specified in `ssl_version()` attribute.
- `FTP_TLS.prot_p()`  
Set up secure data connection.
- `FTP_TLS.prot_c()`  
Set up clear text data connection.

## 20.9 poplib — POP3 protocol client

Source code: [Lib/poplib.py](#)

This module defines a class, `POP3`, which encapsulates a connection to a POP3 server and implements the protocol as defined in [RFC 1725](#). The `POP3` class supports both the minimal and optional command sets. Additionally, this module provides a class `POP3_SSL`, which provides support for connecting to POP3 servers that use SSL as an underlying protocol layer.

Note that POP3, though widely supported, is obsolescent. The implementation quality of POP3 servers varies widely, and too many are quite poor. If your mailserver supports IMAP, you would be better off using the `imaplib.IMAP4` class, as IMAP servers tend to be better implemented.

A single class is provided by the `poplib` module:

**class** `poplib.POP3` (*host* [, *port* [, *timeout* ] ])

This class implements the actual POP3 protocol. The connection is created when the instance is initialized. If *port* is omitted, the standard POP3 port (110) is used. The optional *timeout* parameter specifies a timeout in seconds for the connection attempt (if not specified, the global default timeout setting will be used). Changed in version 2.6: *timeout* was added.

**class** `poplib.POP3_SSL` (*host* [, *port* [, *keyfile* [, *certfile* ] ] ])

This is a subclass of `POP3` that connects to the server over an SSL encrypted socket. If *port* is not specified, 995, the standard POP3-over-SSL port is used. *keyfile* and *certfile* are also optional - they can contain a PEM formatted private key and certificate chain file for the SSL connection. New in version 2.4.

One exception is defined as an attribute of the `poplib` module:

**exception** `poplib.error_proto`

Exception raised on any errors from this module (errors from `socket` module are not caught). The reason for the exception is passed to the constructor as a string.

**See Also:**

**Module** `imaplib` The standard Python IMAP module.

**Frequently Asked Questions About Fetchmail** The FAQ for the **fetchmail** POP/IMAP client collects information on POP3 server variations and RFC noncompliance that may be useful if you need to write an application based on the POP protocol.

### 20.9.1 POP3 Objects

All POP3 commands are represented by methods of the same name, in lower-case; most return the response text sent by the server.

An `POP3` instance has the following methods:

`POP3.set_debuglevel` (*level*)

Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

`POP3.getwelcome` ()

Returns the greeting string sent by the POP3 server.

`POP3.user` (*username*)

Send user command, response should indicate that a password is required.

`POP3.pass_` (*password*)

Send password, response includes message count and mailbox size. Note: the mailbox on the server is locked until `quit` () is called.

`POP3.apop` (*user*, *secret*)

Use the more secure APOP authentication to log into the POP3 server.

`POP3.rpop` (*user*)

Use RPOP authentication (similar to UNIX r-commands) to log into POP3 server.

**POP3.stat()**  
Get mailbox status. The result is a tuple of 2 integers: (message count, mailbox size).

**POP3.list([which])**  
Request message list, result is in the form (response, ['mesg\_num octets', ...], octets). If *which* is set, it is the message to list.

**POP3.retr(which)**  
Retrieve whole message number *which*, and set its seen flag. Result is in form (response, ['line', ...], octets).

**POP3.dele(which)**  
Flag message number *which* for deletion. On most servers deletions are not actually performed until QUIT (the major exception is Eudora QPOP, which deliberately violates the RFCs by doing pending deletes on any disconnect).

**POP3.rset()**  
Remove any deletion marks for the mailbox.

**POP3.noop()**  
Do nothing. Might be used as a keep-alive.

**POP3.quit()**  
Signoff: commit changes, unlock mailbox, drop connection.

**POP3.top(which, howmuch)**  
Retrieves the message header plus *howmuch* lines of the message after the header of message number *which*. Result is in form (response, ['line', ...], octets).

The POP3 TOP command this method uses, unlike the RETR command, doesn't set the message's seen flag; unfortunately, TOP is poorly specified in the RFCs and is frequently broken in off-brand servers. Test this method by hand against the POP3 servers you will use before trusting it.

**POP3.uidl([which])**  
Return message digest (unique id) list. If *which* is specified, result contains the unique id for that message in the form 'response mesgnum uid, otherwise result is list (response, ['mesgnum uid', ...], octets).

Instances of `POP3_SSL` have no additional methods. The interface of this subclass is identical to its parent.

## 20.9.2 POP3 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```
import getpass, poplib

M = poplib.POP3('localhost')
M.user(getpass.getuser())
M.pass_(getpass.getpass())
numMessages = len(M.list()[1])
for i in range(numMessages):
    for j in M.retr(i+1)[1]:
        print j
```

At the end of the module, there is a test section that contains a more extensive example of usage.

## 20.10 `imaplib` — IMAP4 protocol client

Source code: `Lib/imaplib.py`

---

This module defines three classes, `IMAP4`, `IMAP4_SSL` and `IMAP4_stream`, which encapsulate a connection to an IMAP4 server and implement a large subset of the IMAP4rev1 client protocol as defined in

**RFC 2060**. It is backward compatible with IMAP4 (**RFC 1730**) servers, but note that the `STATUS` command is not supported in IMAP4.

Three classes are provided by the `imaplib` module, `IMAP4` is the base class:

**class** `imaplib.IMAP4` (`[host[, port]]`)

This class implements the actual IMAP4 protocol. The connection is created and protocol version (IMAP4 or IMAP4rev1) is determined when the instance is initialized. If `host` is not specified, "" (the local host) is used. If `port` is omitted, the standard IMAP4 port (143) is used.

Three exceptions are defined as attributes of the `IMAP4` class:

**exception** `IMAP4.error`

Exception raised on any errors. The reason for the exception is passed to the constructor as a string.

**exception** `IMAP4.abort`

IMAP4 server errors cause this exception to be raised. This is a sub-class of `IMAP4.error`. Note that closing the instance and instantiating a new one will usually allow recovery from this exception.

**exception** `IMAP4.readonly`

This exception is raised when a writable mailbox has its status changed by the server. This is a sub-class of `IMAP4.error`. Some other client now has write permission, and the mailbox will need to be re-opened to re-obtain write permission.

There's also a subclass for secure connections:

**class** `imaplib.IMAP4_SSL` (`[host[, port[, keyfile[, certfile]]]]`)

This is a subclass derived from `IMAP4` that connects over an SSL encrypted socket (to use this class you need a socket module that was compiled with SSL support). If `host` is not specified, "" (the local host) is used. If `port` is omitted, the standard IMAP4-over-SSL port (993) is used. `keyfile` and `certfile` are also optional - they can contain a PEM formatted private key and certificate chain file for the SSL connection.

The second subclass allows for connections created by a child process:

**class** `imaplib.IMAP4_stream` (`command`)

This is a subclass derived from `IMAP4` that connects to the `stdin/stdout` file descriptors created by passing `command` to `os.popen2()`. New in version 2.3.

The following utility functions are defined:

`imaplib.Internaldate2tuple` (`datestr`)

Parse an IMAP4 `INTERNALDATE` string and return corresponding local time. The return value is a `time.struct_time` instance or `None` if the string has wrong format.

`imaplib.Int2AP` (`num`)

Converts an integer into a string representation using characters from the set [A .. P].

`imaplib.ParseFlags` (`flagstr`)

Converts an IMAP4 `FLAGS` response to a tuple of individual flags.

`imaplib.Time2Internaldate` (`date_time`)

Convert `date_time` to an IMAP4 `INTERNALDATE` representation. The return value is a string in the form: "DD-Mmm-YYYY HH:MM:SS +HHMM" (including double-quotes). The `date_time` argument can be a number

(int or float) representing seconds since epoch (as returned by `time.time()`), a 9-tuple representing local time (as returned by `time.localtime()`), or a double-quoted string. In the last case, it is assumed to already be in the correct format.

Note that IMAP4 message numbers change as the mailbox changes; in particular, after an EXPUNGE command performs deletions the remaining messages are renumbered. So it is highly advisable to use UIDs instead, with the UID command.

At the end of the module, there is a test section that contains a more extensive example of usage.

#### See Also:

Documents describing the protocol, and sources and binaries for servers implementing it, can all be found at the University of Washington's *IMAP Information Center* (<http://www.washington.edu/imap/>).

## 20.10.1 IMAP4 Objects

All IMAP4rev1 commands are represented by methods of the same name, either upper-case or lower-case.

All arguments to commands are converted to strings, except for AUTHENTICATE, and the last argument to APPEND which is passed as an IMAP4 literal. If necessary (the string contains IMAP4 protocol-sensitive characters and isn't enclosed with either parentheses or double quotes) each string is quoted. However, the *password* argument to the LOGIN command is always quoted. If you want to avoid having an argument string quoted (eg: the *flags* argument to STORE) then enclose the string in parentheses (eg: `r'(\Deleted)'`).

Each command returns a tuple: (*type*, [*data*, ...]) where *type* is usually 'OK' or 'NO', and *data* is either the text from the command response, or mandated results from the command. Each *data* is either a string, or a tuple. If a tuple, then the first part is the header of the response, and the second part contains the data (ie: 'literal' value).

The *message\_set* options to commands below is a string specifying one or more messages to be acted upon. It may be a simple message number ('1'), a range of message numbers ('2:4'), or a group of non-contiguous ranges separated by commas ('1:3, 6:9'). A range can contain an asterisk to indicate an infinite upper bound ('3:\*').

An IMAP4 instance has the following methods:

IMAP4.**append** (*mailbox*, *flags*, *date\_time*, *message*)  
Append *message* to named mailbox.

IMAP4.**authenticate** (*mechanism*, *authobject*)  
Authenticate command — requires response processing.

*mechanism* specifies which authentication mechanism is to be used - it should appear in the instance variable *capabilities* in the form AUTH=mechanism.

*authobject* must be a callable object:

```
data = authobject(response)
```

It will be called to process server continuation responses. It should return *data* that will be encoded and sent to server. It should return None if the client abort response \* should be sent instead.

IMAP4.**check** ()  
Checkpoint mailbox on server.

IMAP4.**close** ()  
Close currently selected mailbox. Deleted messages are removed from writable mailbox. This is the recommended command before LOGOUT.

IMAP4.**copy** (*message\_set*, *new\_mailbox*)  
Copy *message\_set* messages onto end of *new\_mailbox*.

- IMAP4.create** (*mailbox*)  
Create new mailbox named *mailbox*.
- IMAP4.delete** (*mailbox*)  
Delete old mailbox named *mailbox*.
- IMAP4.deleteacl** (*mailbox, who*)  
Delete the ACLs (remove any rights) set for *who* on mailbox. New in version 2.4.
- IMAP4.expunge** ()  
Permanently remove deleted items from selected mailbox. Generates an EXPUNGE response for each deleted message. Returned data contains a list of EXPUNGE message numbers in order received.
- IMAP4.fetch** (*message\_set, message\_parts*)  
Fetch (parts of) messages. *message\_parts* should be a string of message part names enclosed within parentheses, eg: " (UID BODY [TEXT] ) ". Returned data are tuples of message part envelope and data.
- IMAP4.getacl** (*mailbox*)  
Get the ACLs for *mailbox*. The method is non-standard, but is supported by the Cyrus server.
- IMAP4.getannotation** (*mailbox, entry, attribute*)  
Retrieve the specified ANNOTATIONS for *mailbox*. The method is non-standard, but is supported by the Cyrus server. New in version 2.5.
- IMAP4.getquota** (*root*)  
Get the *quota root*'s resource usage and limits. This method is part of the IMAP4 QUOTA extension defined in rfc2087. New in version 2.3.
- IMAP4.getquotaroot** (*mailbox*)  
Get the list of *quota roots* for the named *mailbox*. This method is part of the IMAP4 QUOTA extension defined in rfc2087. New in version 2.3.
- IMAP4.list** ([*directory* [, *pattern* ]])  
List mailbox names in *directory* matching *pattern*. *directory* defaults to the top-level mail folder, and *pattern* defaults to match anything. Returned data contains a list of LIST responses.
- IMAP4.login** (*user, password*)  
Identify the client using a plaintext password. The *password* will be quoted.
- IMAP4.login\_cram\_md5** (*user, password*)  
Force use of CRAM-MD5 authentication when identifying the client to protect the password. Will only work if the server CAPABILITY response includes the phrase AUTH=CRAM-MD5. New in version 2.3.
- IMAP4.logout** ()  
Shutdown connection to server. Returns server BYE response.
- IMAP4.lsub** ([*directory* [, *pattern* ]])  
List subscribed mailbox names in *directory* matching *pattern*. *directory* defaults to the top level directory and *pattern* defaults to match any mailbox. Returned data are tuples of message part envelope and data.
- IMAP4.myrights** (*mailbox*)  
Show my ACLs for a mailbox (i.e. the rights that I have on mailbox). New in version 2.4.
- IMAP4.namespace** ()  
Returns IMAP namespaces as defined in RFC2342. New in version 2.3.
- IMAP4.noop** ()  
Send NOOP to server.
- IMAP4.open** (*host, port*)  
Opens socket to *port* at *host*. This method is implicitly called by the `IMAP4` constructor. The connection objects

established by this method will be used in the `read`, `readline`, `send`, and `shutdown` methods. You may override this method.

IMAP4.**partial** (*message\_num*, *message\_part*, *start*, *length*)

Fetch truncated part of a message. Returned data is a tuple of message part envelope and data.

IMAP4.**proxyauth** (*user*)

Assume authentication as *user*. Allows an authorised administrator to proxy into any user's mailbox. New in version 2.3.

IMAP4.**read** (*size*)

Reads *size* bytes from the remote server. You may override this method.

IMAP4.**readline** ()

Reads one line from the remote server. You may override this method.

IMAP4.**recent** ()

Prompt server for an update. Returned data is `None` if no new messages, else value of RECENT response.

IMAP4.**rename** (*oldmailbox*, *newmailbox*)

Rename mailbox named *oldmailbox* to *newmailbox*.

IMAP4.**response** (*code*)

Return data for response *code* if received, or `None`. Returns the given code, instead of the usual type.

IMAP4.**search** (*charset*, *criterion*[, ... ])

Search mailbox for matching messages. *charset* may be `None`, in which case no CHARSET will be specified in the request to the server. The IMAP protocol requires that at least one criterion be specified; an exception will be raised when the server returns an error.

Example:

```
# M is a connected IMAP4 instance...
typ, msgnums = M.search(None, 'FROM', '"LDJ"')

# or:
typ, msgnums = M.search(None, '(FROM "LDJ")')
```

IMAP4.**select** ([*mailbox*[, *readonly*] ])

Select a mailbox. Returned data is the count of messages in *mailbox* (EXISTS response). The default *mailbox* is 'INBOX'. If the *readonly* flag is set, modifications to the mailbox are not allowed.

IMAP4.**send** (*data*)

Sends *data* to the remote server. You may override this method.

IMAP4.**setacl** (*mailbox*, *who*, *what*)

Set an ACL for *mailbox*. The method is non-standard, but is supported by the Cyrus server.

IMAP4.**setannotation** (*mailbox*, *entry*, *attribute*[, ... ])

Set ANNOTATIONS for *mailbox*. The method is non-standard, but is supported by the Cyrus server. New in version 2.5.

IMAP4.**setquota** (*root*, *limits*)

Set the quota *root*'s resource *limits*. This method is part of the IMAP4 QUOTA extension defined in rfc2087. New in version 2.3.

IMAP4.**shutdown** ()

Close connection established in open. This method is implicitly called by `IMAP4.logout()`. You may override this method.

IMAP4.**socket** ()

Returns socket instance used to connect to server.

IMAP4.**sort** (*sort\_criteria*, *charset*, *search\_criterion*[, ... ])

The `sort` command is a variant of `search` with sorting semantics for the results. Returned data contains a space separated list of matching message numbers.

Sort has two arguments before the *search\_criterion* argument(s); a parenthesized list of *sort\_criteria*, and the searching *charset*. Note that unlike `search`, the searching *charset* argument is mandatory. There is also a `uid sort` command which corresponds to `sort` the way that `uid search` corresponds to `search`. The `sort` command first searches the mailbox for messages that match the given searching criteria using the *charset* argument for the interpretation of strings in the searching criteria. It then returns the numbers of matching messages.

This is an IMAP4rev1 extension command.

IMAP4.**status** (*mailbox*, *names*)

Request named status conditions for *mailbox*.

IMAP4.**store** (*message\_set*, *command*, *flag\_list*)

Alters flag dispositions for messages in mailbox. *command* is specified by section 6.4.6 of **RFC 2060** as being one of “FLAGS”, “+FLAGS”, or “-FLAGS”, optionally with a suffix of “.SILENT”.

For example, to set the delete flag on all messages:

```
typ, data = M.search(None, 'ALL')
for num in data[0].split():
    M.store(num, '+FLAGS', '\\Deleted')
M.expunge()
```

IMAP4.**subscribe** (*mailbox*)

Subscribe to new mailbox.

IMAP4.**thread** (*threading\_algorithm*, *charset*, *search\_criterion*[, ... ])

The `thread` command is a variant of `search` with threading semantics for the results. Returned data contains a space separated list of thread members.

Thread members consist of zero or more messages numbers, delimited by spaces, indicating successive parent and child.

Thread has two arguments before the *search\_criterion* argument(s); a *threading\_algorithm*, and the searching *charset*. Note that unlike `search`, the searching *charset* argument is mandatory. There is also a `uid thread` command which corresponds to `thread` the way that `uid search` corresponds to `search`. The `thread` command first searches the mailbox for messages that match the given searching criteria using the *charset* argument for the interpretation of strings in the searching criteria. It then returns the matching messages threaded according to the specified threading algorithm.

This is an IMAP4rev1 extension command. New in version 2.4.

IMAP4.**uid** (*command*, *arg*[, ... ])

Execute command args with messages identified by UID, rather than message number. Returns response appropriate to command. At least one argument must be supplied; if none are provided, the server will return an error and an exception will be raised.

IMAP4.**unsubscribe** (*mailbox*)

Unsubscribe from old mailbox.

IMAP4.**xatom** (*name*[, *arg*[, ... ]])

Allow simple extension commands notified by server in CAPABILITY response.

Instances of `IMAP4_SSL` have just one additional method:

`IMAP4_SSL.ssl()`

Returns `SSLObject` instance used for the secure connection with the server.

The following attributes are defined on instances of `IMAP4`:

`IMAP4.PROTOCOL_VERSION`

The most recent supported protocol in the `CAPABILITY` response from the server.

`IMAP4.debug`

Integer value to control debugging output. The initialize value is taken from the module variable `Debug`. Values greater than three trace each command.

## 20.10.2 IMAP4 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```
import getpass, imaplib

M = imaplib.IMAP4()
M.login(getpass.getuser(), getpass.getpass())
M.select()
typ, data = M.search(None, 'ALL')
for num in data[0].split():
    typ, data = M.fetch(num, '(RFC822)')
    print 'Message %s\n%s\n' % (num, data[0][1])
M.close()
M.logout()
```

## 20.11 nntplib — NNTP protocol client

Source code: [Lib/nntplib.py](#)

This module defines the class `NNTP` which implements the client side of the NNTP protocol. It can be used to implement a news reader or poster, or automated news processors. For more information on NNTP (Network News Transfer Protocol), see Internet [RFC 977](#).

Here are two small examples of how it can be used. To list some statistics about a newsgroup and print the subjects of the last 10 articles:

```
>>> s = NNTP('news.gmane.org')
>>> resp, count, first, last, name = s.group('gmane.comp.python.committers')
>>> print 'Group', name, 'has', count, 'articles, range', first, 'to', last
Group gmane.comp.python.committers has 1071 articles, range 1 to 1071
>>> resp, subs = s.xhdr('subject', first + '-' + last)
>>> for id, sub in subs[-10:]: print id, sub
...
1062 Re: Mercurial Status?
1063 Re: [python-committers] (Windows) buildbots on 3.x
1064 Re: Mercurial Status?
1065 Re: Mercurial Status?
1066 Python 2.6.6 status
1067 Commit Privileges for Ask Solem
1068 Re: Commit Privileges for Ask Solem
```

```
1069 Re: Commit Privileges for Ask Solem
1070 Re: Commit Privileges for Ask Solem
1071 2.6.6 rc 2
>>> s.quit()
'205 Bye!'
```

To post an article from a file (this assumes that the article has valid headers, and that you have right to post on the particular newsgroup):

```
>>> s = NNTP('news.gmane.org')
>>> f = open('/tmp/article')
>>> s.post(f)
'240 Article posted successfully.'
>>> s.quit()
'205 Bye!'
```

The module itself defines the following items:

**class** `nntplib.NNTP` (*host* [, *port* [, *user* [, *password* [, *readermode*] [, *usenetr*]]]])

Return a new instance of the `NNTP` class, representing a connection to the NNTP server running on host *host*, listening at port *port*. The default *port* is 119. If the optional *user* and *password* are provided, or if suitable credentials are present in `/.netrc` and the optional flag *usenetr* is true (the default), the `AUTHINFO USER` and `AUTHINFO PASS` commands are used to identify and authenticate the user to the server. If the optional flag *readermode* is true, then a `mode reader` command is sent before authentication is performed. Reader mode is sometimes necessary if you are connecting to an NNTP server on the local machine and intend to call reader-specific commands, such as `group`. If you get unexpected `NNTPPermanentErrors`, you might need to set *readermode*. *readermode* defaults to `None`. *usenetr* defaults to `True`. Changed in version 2.4: *usenetr* argument added.

**exception** `nntplib.NNTPError`

Derived from the standard exception `Exception`, this is the base class for all exceptions raised by the `nntplib` module.

**exception** `nntplib.NNTPReplyError`

Exception raised when an unexpected reply is received from the server. For backwards compatibility, the exception `error_reply` is equivalent to this class.

**exception** `nntplib.NNTPTemporaryError`

Exception raised when an error code in the range 400–499 is received. For backwards compatibility, the exception `error_temp` is equivalent to this class.

**exception** `nntplib.NNTPPermanentError`

Exception raised when an error code in the range 500–599 is received. For backwards compatibility, the exception `error_perm` is equivalent to this class.

**exception** `nntplib.NNTPProtocolError`

Exception raised when a reply is received from the server that does not begin with a digit in the range 1–5. For backwards compatibility, the exception `error_proto` is equivalent to this class.

**exception** `nntplib.NNTPDataError`

Exception raised when there is some error in the response data. For backwards compatibility, the exception `error_data` is equivalent to this class.

### 20.11.1 NNTP Objects

NNTP instances have the following methods. The *response* that is returned as the first item in the return tuple of almost all methods is the server's response: a string beginning with a three-digit code. If the server's response indicates an error, the method raises one of the above exceptions.

**NNTP.getwelcome()**

Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

**NNTP.set\_debuglevel(*level*)**

Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request or response. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the connection (including message text).

**NNTP.newgroups(*date*, *time*[, *file*])**

Send a NEWGROUPS command. The *date* argument should be a string of the form 'yyymmdd' indicating the date, and *time* should be a string of the form 'hhmmss' indicating the time. Return a pair (*response*, *groups*) where *groups* is a list of group names that are new since the given date and time. If the *file* parameter is supplied, then the output of the NEWGROUPS command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.newnews(*group*, *date*, *time*[, *file*])**

Send a NEWNEWS command. Here, *group* is a group name or '\*', and *date* and *time* have the same meaning as for `newgroups()`. Return a pair (*response*, *articles*) where *articles* is a list of message ids. If the *file* parameter is supplied, then the output of the NEWNEWS command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.list([*file*])**

Send a LIST command. Return a pair (*response*, *list*) where *list* is a list of tuples. Each tuple has the form (*group*, *last*, *first*, *flag*), where *group* is a group name, *last* and *first* are the last and first article numbers (as strings), and *flag* is 'y' if posting is allowed, 'n' if not, and 'm' if the newsgroup is moderated. (Note the ordering: *last*, *first*.) If the *file* parameter is supplied, then the output of the LIST command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.descriptions(*grouppattern*)**

Send a LIST NEWSGROUPS command, where *grouppattern* is a wildmat string as specified in RFC2980 (it's essentially the same as DOS or UNIX shell wildcard strings). Return a pair (*response*, *list*), where *list* is a list of tuples containing (*name*, *title*). New in version 2.4.

**NNTP.description(*group*)**

Get a description for a single group *group*. If more than one group matches (if 'group' is a real wildmat string), return the first match. If no group matches, return an empty string.

This elides the response code from the server. If the response code is needed, use `descriptions()`. New in version 2.4.

**NNTP.group(*name*)**

Send a GROUP command, where *name* is the group name. Return a tuple (*response*, *count*, *first*, *last*, *name*) where *count* is the (estimated) number of articles in the group, *first* is the first article number in the group, *last* is the last article number in the group, and *name* is the group name. The numbers are returned as strings.

**NNTP.help([*file*])**

Send a HELP command. Return a pair (*response*, *list*) where *list* is a list of help strings. If the *file* parameter is supplied, then the output of the HELP command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling

`write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.stat** (*id*)

Send a STAT command, where *id* is the message id (enclosed in '<' and '>') or an article number (as a string). Return a triple (*response*, *number*, *id*) where *number* is the article number (as a string) and *id* is the message id (enclosed in '<' and '>').

**NNTP.next** ()

Send a NEXT command. Return as for `stat()`.

**NNTP.last** ()

Send a LAST command. Return as for `stat()`.

**NNTP.head** (*id*)

Send a HEAD command, where *id* has the same meaning as for `stat()`. Return a tuple (*response*, *number*, *id*, *list*) where the first three are the same as for `stat()`, and *list* is a list of the article's headers (an uninterpreted list of lines, without trailing newlines).

**NNTP.body** (*id* [, *file* ])

Send a BODY command, where *id* has the same meaning as for `stat()`. If the *file* parameter is supplied, then the body is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the body. Return as for `head()`. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.article** (*id*)

Send an ARTICLE command, where *id* has the same meaning as for `stat()`. Return as for `head()`.

**NNTP.slave** ()

Send a SLAVE command. Return the server's *response*.

**NNTP.xhdr** (*header*, *string* [, *file* ])

Send an XHDR command. This command is not defined in the RFC but is a common extension. The *header* argument is a header keyword, e.g. 'subject'. The *string* argument should have the form 'first-last' where *first* and *last* are the first and last article numbers to search. Return a pair (*response*, *list*), where *list* is a list of pairs (*id*, *text*), where *id* is an article number (as a string) and *text* is the text of the requested header for that article. If the *file* parameter is supplied, then the output of the XHDR command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.post** (*file*)

Post an article using the POST command. The *file* argument is an open file object which is read until EOF using its `readline()` method. It should be a well-formed news article, including the required headers. The `post()` method automatically escapes lines beginning with ..

**NNTP.ihave** (*id*, *file*)

Send an IHAVE command. *id* is a message id (enclosed in '<' and '>'). If the response is not an error, treat *file* exactly as for the `post()` method.

**NNTP.date** ()

Return a triple (*response*, *date*, *time*), containing the current date and time in a form suitable for the `newnews()` and `newgroups()` methods. This is an optional NNTP extension, and may not be supported by all servers.

**NNTP.xgtitle** (*name* [, *file* ])

Process an XGTITLE command, returning a pair (*response*, *list*), where *list* is a list of tuples containing (*name*, *title*). If the *file* parameter is supplied, then the output of the XGTITLE command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied,

then the returned *list* is an empty list. This is an optional NNTP extension, and may not be supported by all servers.

RFC2980 says “It is suggested that this extension be deprecated”. Use `descriptions()` or `description()` instead.

NNTP **.xover** (*start*, *end*[, *file* ])

Return a pair (*resp*, *list*). *list* is a list of tuples, one for each article in the range delimited by the *start* and *end* article numbers. Each tuple is of the form (*article number*, *subject*, *poster*, *date*, *id*, *references*, *size*, *lines*). If the *file* parameter is supplied, then the output of the XOVER command is stored in a file. If *file* is a string, then the method will open a file object with that name, write to it then close it. If *file* is a file object, then it will start calling `write()` on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list. This is an optional NNTP extension, and may not be supported by all servers.

NNTP **.xpath** (*id*)

Return a pair (*resp*, *path*), where *path* is the directory path to the article with message ID *id*. This is an optional NNTP extension, and may not be supported by all servers.

NNTP **.quit** ()

Send a QUIT command and close the connection. Once this method has been called, no other methods of the NNTP object should be called.

## 20.12 smtplib — SMTP protocol client

**Source code:** `Lib/smtpplib.py`

The `smtplib` module defines an SMTP client session object that can be used to send mail to any Internet machine with an SMTP or ESMTP listener daemon. For details of SMTP and ESMTP operation, consult **RFC 821** (Simple Mail Transfer Protocol) and **RFC 1869** (SMTP Service Extensions).

**class** `smtplib.SMTP` ([*host*[, *port*[, *local\_hostname*[, *timeout* ] ] ]])

A `SMTP` instance encapsulates an SMTP connection. It has methods that support a full repertoire of SMTP and ESMTP operations. If the optional host and port parameters are given, the `SMTP.connect()` method is called with those parameters during initialization. An `SMTPConnectError` is raised if the specified host doesn't respond correctly. The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

For normal use, you should only require the initialization/connect, `sendmail()`, and `quit()` methods. An example is included below. Changed in version 2.6: *timeout* was added.

**class** `smtplib.SMTP_SSL` ([*host*[, *port*[, *local\_hostname*[, *keyfile*[, *certfile*[, *timeout* ] ] ] ]])

A `SMTP_SSL` instance behaves exactly the same as instances of `SMTP`. `SMTP_SSL` should be used for situations where SSL is required from the beginning of the connection and using `starttls()` is not appropriate. If *host* is not specified, the local host is used. If *port* is omitted, the standard SMTP-over-SSL port (465) is used. *keyfile* and *certfile* are also optional, and can contain a PEM formatted private key and certificate chain file for the SSL connection. The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). New in version 2.6.

**class** `smtplib.LMTP` ([*host*[, *port*[, *local\_hostname* ] ]])

The LMTP protocol, which is very similar to ESMTP, is heavily based on the standard SMTP client. It's common to use Unix sockets for LMTP, so our `connect()` method must support that as well as a regular host:port server. To specify a Unix socket, you must use an absolute path for *host*, starting with a '/

Authentication is supported, using the regular SMTP mechanism. When using a Unix socket, LMTP generally don't support or require any authentication, but your mileage might vary. New in version 2.6.

A nice selection of exceptions is defined as well:

**exception** `smtplib.SMTPException`

Base exception class for all exceptions raised by this module.

**exception** `smtplib.SMTPServerDisconnected`

This exception is raised when the server unexpectedly disconnects, or when an attempt is made to use the `SMTP` instance before connecting it to a server.

**exception** `smtplib.SMTPResponseException`

Base class for all exceptions that include an SMTP error code. These exceptions are generated in some instances when the SMTP server returns an error code. The error code is stored in the `smtp_code` attribute of the error, and the `smtp_error` attribute is set to the error message.

**exception** `smtplib.SMTPSenderRefused`

Sender address refused. In addition to the attributes set by on all `SMTPResponseException` exceptions, this sets 'sender' to the string that the SMTP server refused.

**exception** `smtplib.SMTPRecipientsRefused`

All recipient addresses refused. The errors for each recipient are accessible through the attribute `recipients`, which is a dictionary of exactly the same sort as `SMTP.sendmail()` returns.

**exception** `smtplib.SMTPDataError`

The SMTP server refused to accept the message data.

**exception** `smtplib.SMTPConnectError`

Error occurred during establishment of a connection with the server.

**exception** `smtplib.SMTPHeloError`

The server refused our HELO message.

**exception** `smtplib.SMTPAuthenticationError`

SMTP authentication went wrong. Most probably the server didn't accept the username/password combination provided.

**See Also:**

**RFC 821 - Simple Mail Transfer Protocol** Protocol definition for SMTP. This document covers the model, operating procedure, and protocol details for SMTP.

**RFC 1869 - SMTP Service Extensions** Definition of the ESMTP extensions for SMTP. This describes a framework for extending SMTP with new commands, supporting dynamic discovery of the commands provided by the server, and defines a few additional commands.

## 20.12.1 SMTP Objects

An `SMTP` instance has the following methods:

`SMTP.set_debuglevel` (*level*)

Set the debug output level. A true value for *level* results in debug messages for connection and for all messages sent to and received from the server.

`SMTP.connect` (*[host[, port]]*)

Connect to a host on a given port. The defaults are to connect to the local host at the standard SMTP port (25). If the hostname ends with a colon (':') followed by a number, that suffix will be stripped off and the number interpreted as the port number to use. This method is automatically invoked by the constructor if a host is specified during instantiation.

`SMTP.docmd` (*cmd[, argstring]*)

Send a command *cmd* to the server. The optional argument *argstring* is simply concatenated to the command, separated by a space.

This returns a 2-tuple composed of a numeric response code and the actual response line (multiline responses are joined into one long line.)

In normal operation it should not be necessary to call this method explicitly. It is used to implement other methods and may be useful for testing private extensions.

If the connection to the server is lost while waiting for the reply, `SMTPServerDisconnected` will be raised.

`SMTP.helo` (`[hostname]`)

Identify yourself to the SMTP server using HELO. The hostname argument defaults to the fully qualified domain name of the local host. The message returned by the server is stored as the `helo_resp` attribute of the object.

In normal operation it should not be necessary to call this method explicitly. It will be implicitly called by the `sendmail()` when necessary.

`SMTP.ehlo` (`[hostname]`)

Identify yourself to an ESMTP server using EHLO. The hostname argument defaults to the fully qualified domain name of the local host. Examine the response for ESMTP option and store them for use by `has_extn()`. Also sets several informational attributes: the message returned by the server is stored as the `ehlo_resp` attribute, `does_esmtp` is set to true or false depending on whether the server supports ESMTP, and `esmtp_features` will be a dictionary containing the names of the SMTP service extensions this server supports, and their parameters (if any).

Unless you wish to use `has_extn()` before sending mail, it should not be necessary to call this method explicitly. It will be implicitly called by `sendmail()` when necessary.

`SMTP.ehlo_or_helo_if_needed` ()

This method call `ehlo()` and or `helo()` if there has been no previous EHLO or HELO command this session. It tries ESMTP EHLO first.

**SMTPHelloError** The server didn't reply properly to the HELO greeting.

New in version 2.6.

`SMTP.has_extn` (`name`)

Return `True` if `name` is in the set of SMTP service extensions returned by the server, `False` otherwise. Case is ignored.

`SMTP.verify` (`address`)

Check the validity of an address on this server using SMTP VRFY. Returns a tuple consisting of code 250 and a full RFC 822 address (including human name) if the user address is valid. Otherwise returns an SMTP error code of 400 or greater and an error string.

---

**Note:** Many sites disable SMTP VRFY in order to foil spammers.

---

`SMTP.login` (`user, password`)

Log in on an SMTP server that requires authentication. The arguments are the username and the password to authenticate with. If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first. This method will return normally if the authentication was successful, or may raise the following exceptions:

**SMTPHelloError** The server didn't reply properly to the HELO greeting.

**SMTPAuthenticationError** The server didn't accept the username/password combination.

**SMTPException** No suitable authentication method was found.

`SMTP.starttls` (`[keyfile[, certfile]]`)

Put the SMTP connection in TLS (Transport Layer Security) mode. All SMTP commands that follow will be encrypted. You should then call `ehlo()` again.

If *keyfile* and *certfile* are provided, these are passed to the `socket` module's `ssl()` function.

If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first. Changed in version 2.6.

**SMTPHelloError** The server didn't reply properly to the HELO greeting.

**SMTPException** The server does not support the STARTTLS extension.

Changed in version 2.6.

**RuntimeError** SSL/TLS support is not available to your Python interpreter.

SMTP. **sendmail** (*from\_addr*, *to\_addrs*, *msg* [, *mail\_options*, *rcpt\_options* ])

Send mail. The required arguments are an **RFC 822** from-address string, a list of **RFC 822** to-address strings (a bare string will be treated as a list with 1 address), and a message string. The caller may pass a list of ESMTP options (such as `8bitmime`) to be used in MAIL FROM commands as *mail\_options*. ESMTP options (such as DSN commands) that should be used with all RCPT commands can be passed as *rcpt\_options*. (If you need to use different ESMTP options to different recipients you have to use the low-level methods such as `mail()`, `rcpt()` and `data()` to send the message.)

---

**Note:** The *from\_addr* and *to\_addrs* parameters are used to construct the message envelope used by the transport agents. The SMTP does not modify the message headers in any way.

---

If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first. If the server does ESMTP, message size and each of the specified options will be passed to it (if the option is in the feature set the server advertises). If EHLO fails, HELO will be tried and ESMTP options suppressed.

This method will return normally if the mail is accepted for at least one recipient. Otherwise it will raise an exception. That is, if this method does not raise an exception, then someone should get your mail. If this method does not raise an exception, it returns a dictionary, with one entry for each recipient that was refused. Each entry contains a tuple of the SMTP error code and the accompanying error message sent by the server.

This method may raise the following exceptions:

**SMTPRecipientsRefused** All recipients were refused. Nobody got the mail. The `recipients` attribute of the exception object is a dictionary with information about the refused recipients (like the one returned when at least one recipient was accepted).

**SMTPHelloError** The server didn't reply properly to the HELO greeting.

**SMTPSenderRefused** The server didn't accept the *from\_addr*.

**SMTPDataError** The server replied with an unexpected error code (other than a refusal of a recipient).

Unless otherwise noted, the connection will be open even after an exception is raised.

SMTP. **quit** ()

Terminate the SMTP session and close the connection. Return the result of the SMTP QUIT command. Changed in version 2.6: Return a value.

Low-level methods corresponding to the standard SMTP/ESMTP commands HELP, RSET, NOOP, MAIL, RCPT, and DATA are also supported. Normally these do not need to be called directly, so they are not documented here. For details, consult the module code.

### 20.12.2 SMTP Example

This example prompts the user for addresses needed in the message envelope ('To' and 'From' addresses), and the message to be delivered. Note that the headers to be included with the message must be included in the message as

entered; this example doesn't do any processing of the [RFC 822](#) headers. In particular, the 'To' and 'From' addresses must be included in the message headers explicitly.

```
import smtplib

def prompt(prompt):
    return raw_input(prompt).strip()

fromaddr = prompt("From: ")
toaddrs = prompt("To: ").split()
print "Enter message, end with ^D (Unix) or ^Z (Windows):"

# Add the From: and To: headers at the start!
msg = ("From: %s\r\nTo: %s\r\n\r\n"
       % (fromaddr, ", ".join(toaddrs)))
while 1:
    try:
        line = raw_input()
    except EOFError:
        break
    if not line:
        break
    msg = msg + line

print "Message length is " + repr(len(msg))

server = smtplib.SMTP('localhost')
server.set_debuglevel(1)
server.sendmail(fromaddr, toaddrs, msg)
server.quit()
```

---

**Note:** In general, you will want to use the [email](#) package's features to construct an email message, which you can then convert to a string and send via `sendmail()`; see *email: Examples*.

---

## 20.13 smtpd — SMTP Server

**Source code:** [Lib/smtpd.py](#)

---

This module offers several classes to implement SMTP servers. One is a generic do-nothing implementation, which can be overridden, while the other two offer specific mail-sending strategies.

### 20.13.1 SMTPServer Objects

**class** `smtpd.SMTPServer` (*localaddr*, *remoteaddr*)

Create a new `SMTPServer` object, which binds to local address *localaddr*. It will treat *remoteaddr* as an upstream SMTP relay. It inherits from `asyncore.dispatcher`, and so will insert itself into `asyncore`'s event loop on instantiation.

**process\_message** (*peer*, *mailfrom*, *rcpttos*, *data*)

Raise `NotImplementedError` exception. Override this in subclasses to do something useful with this

message. Whatever was passed in the constructor as *remoteaddr* will be available as the `_remoteaddr` attribute. *peer* is the remote host's address, *mailfrom* is the envelope originator, *rcpttos* are the envelope recipients and *data* is a string containing the contents of the e-mail (which should be in **RFC 2822** format).

### 20.13.2 DebuggingServer Objects

**class** `smtpd.DebuggingServer` (*localaddr*, *remoteaddr*)

Create a new debugging server. Arguments are as per `SMTPServer`. Messages will be discarded, and printed on stdout.

### 20.13.3 PureProxy Objects

**class** `smtpd.PureProxy` (*localaddr*, *remoteaddr*)

Create a new pure proxy server. Arguments are as per `SMTPServer`. Everything will be relayed to *remoteaddr*. Note that running this has a good chance to make you into an open relay, so please be careful.

### 20.13.4 MailmanProxy Objects

**class** `smtpd.MailmanProxy` (*localaddr*, *remoteaddr*)

Create a new pure proxy server. Arguments are as per `SMTPServer`. Everything will be relayed to *remoteaddr*, unless local mailman configurations knows about an address, in which case it will be handled via mailman. Note that running this has a good chance to make you into an open relay, so please be careful.

## 20.14 telnetlib — Telnet client

**Source code:** [Lib/telnetlib.py](#)

---

The `telnetlib` module provides a `Telnet` class that implements the Telnet protocol. See **RFC 854** for details about the protocol. In addition, it provides symbolic constants for the protocol characters (see below), and for the telnet options. The symbolic names of the telnet options follow the definitions in `arpa/telnet.h`, with the leading `TELOPT_` removed. For symbolic names of options which are traditionally not included in `arpa/telnet.h`, see the module source itself.

The symbolic constants for the telnet commands are: IAC, DONT, DO, WONT, WILL, SE (Subnegotiation End), NOP (No Operation), DM (Data Mark), BRK (Break), IP (Interrupt process), AO (Abort output), AYT (Are You There), EC (Erase Character), EL (Erase Line), GA (Go Ahead), SB (Subnegotiation Begin).

**class** `telnetlib.Telnet` (*host*[, *port*[, *timeout*]])

`Telnet` represents a connection to a Telnet server. The instance is initially not connected by default; the `open()` method must be used to establish a connection. Alternatively, the host name and optional port number can be passed to the constructor, to, in which case the connection to the server will be established before the constructor returns. The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

Do not reopen an already connected instance.

This class has many `read_*()` methods. Note that some of them raise `EOFError` when the end of the connection is read, because they can return an empty string for other reasons. See the individual descriptions below. Changed in version 2.6: *timeout* was added.

**See Also:**

**RFC 854 - Telnet Protocol Specification** Definition of the Telnet protocol.

## 20.14.1 Telnet Objects

`Telnet` instances have the following methods:

`Telnet.read_until(expected[, timeout ])`

Read until a given string, *expected*, is encountered or until *timeout* seconds have passed.

When no match is found, return whatever is available instead, possibly the empty string. Raise `EOFError` if the connection is closed and no cooked data is available.

`Telnet.read_all()`

Read all data until EOF; block until connection closed.

`Telnet.read_some()`

Read at least one byte of cooked data unless EOF is hit. Return "" if EOF is hit. Block if no data is immediately available.

`Telnet.read_very_eager()`

Read everything that can be without blocking in I/O (eager).

Raise `EOFError` if connection closed and no cooked data available. Return "" if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

`Telnet.read_eager()`

Read readily available data.

Raise `EOFError` if connection closed and no cooked data available. Return "" if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

`Telnet.read_lazy()`

Process and return data already in the queues (lazy).

Raise `EOFError` if connection closed and no data available. Return "" if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

`Telnet.read_very_lazy()`

Return any data available in the cooked queue (very lazy).

Raise `EOFError` if connection closed and no data available. Return "" if no cooked data available otherwise. This method never blocks.

`Telnet.read_sb_data()`

Return the data collected between a SB/SE pair (suboption begin/end). The callback should access these data when it was invoked with a SE command. This method never blocks. New in version 2.3.

`Telnet.open(host[, port[, timeout ]])`

Connect to a host. The optional second argument is the port number, which defaults to the standard Telnet port (23). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

Do not try to reopen an already connected instance. Changed in version 2.6: *timeout* was added.

`Telnet.msg(msg[, *args ])`

Print a debug message when the debug level is > 0. If extra arguments are present, they are substituted in the message using the standard string formatting operator.

`Telnet.set_debuglevel(debuglevel)`

Set the debug level. The higher the value of *debuglevel*, the more debug output you get (on `sys.stdout`).

`Telnet.close()`  
Close the connection.

`Telnet.get_socket()`  
Return the socket object used internally.

`Telnet.fileno()`  
Return the file descriptor of the socket object used internally.

`Telnet.write(buffer)`  
Write a string to the socket, doubling any IAC characters. This can block if the connection is blocked. May raise `socket.error` if the connection is closed.

`Telnet.interact()`  
Interaction function, emulates a very dumb Telnet client.

`Telnet.mt_interact()`  
Multithreaded version of `interact()`.

`Telnet.expect(list[, timeout])`  
Read until one from a list of a regular expressions matches.

The first argument is a list of regular expressions, either compiled (`re.RegexObject` instances) or uncompiled (strings). The optional second argument is a timeout, in seconds; the default is to block indefinitely.

Return a tuple of three items: the index in the list of the first regular expression that matches; the match object returned; and the text read up till and including the match.

If end of file is found and no text was read, raise `EOFError`. Otherwise, when nothing matches, return `(-1, None, text)` where `text` is the text received so far (may be the empty string if a timeout happened).

If a regular expression ends with a greedy match (such as `.*`) or if more than one expression can match the same input, the results are non-deterministic, and may depend on the I/O timing.

`Telnet.set_option_negotiation_callback(callback)`  
Each time a telnet option is read on the input flow, this `callback` (if set) is called with the following parameters : `callback(telnet socket, command (DO/DONT/WILL/WONT), option)`. No other action is done afterwards by `telnetlib`.

### 20.14.2 Telnet Example

A simple example illustrating typical use:

```
import getpass
import sys
import telnetlib

HOST = "localhost"
user = raw_input("Enter your remote account: ")
password = getpass.getpass()

tn = telnetlib.Telnet(HOST)

tn.read_until("login: ")
tn.write(user + "\n")
if password:
    tn.read_until("Password: ")
    tn.write(password + "\n")
```

```
tn.write("ls\n")
tn.write("exit\n")

print tn.read_all()
```

## 20.15 uuid — UUID objects according to RFC 4122

New in version 2.5. This module provides immutable `UUID` objects (the `UUID` class) and the functions `uuid1()`, `uuid3()`, `uuid4()`, `uuid5()` for generating version 1, 3, 4, and 5 UUIDs as specified in [RFC 4122](#).

If all you want is a unique ID, you should probably call `uuid1()` or `uuid4()`. Note that `uuid1()` may compromise privacy since it creates a UUID containing the computer's network address. `uuid4()` creates a random UUID.

**class** `uuid.UUID` (`[hex[, bytes[, bytes_le[, fields[, int[, version]]]]]`)

Create a UUID from either a string of 32 hexadecimal digits, a string of 16 bytes as the `bytes` argument, a string of 16 bytes in little-endian order as the `bytes_le` argument, a tuple of six integers (32-bit `time_low`, 16-bit `time_mid`, 16-bit `time_hi_version`, 8-bit `clock_seq_hi_variant`, 8-bit `clock_seq_low`, 48-bit `node`) as the `fields` argument, or a single 128-bit integer as the `int` argument. When a string of hex digits is given, curly braces, hyphens, and a URN prefix are all optional. For example, these expressions all yield the same UUID:

```
UUID('{12345678-1234-5678-1234-567812345678}')
UUID('12345678123456781234567812345678')
UUID('urn:uuid:12345678-1234-5678-1234-567812345678')
UUID(bytes='\x12\x34\x56\x78'*4)
UUID(bytes_le='\x78\x56\x34\x12\x34\x12\x78\x56' +
             '\x12\x34\x56\x78\x12\x34\x56\x78')
UUID(fields=(0x12345678, 0x1234, 0x5678, 0x12, 0x34, 0x567812345678))
UUID(int=0x12345678123456781234567812345678)
```

Exactly one of `hex`, `bytes`, `bytes_le`, `fields`, or `int` must be given. The `version` argument is optional; if given, the resulting UUID will have its variant and version number set according to RFC 4122, overriding bits in the given `hex`, `bytes`, `bytes_le`, `fields`, or `int`.

`UUID` instances have these read-only attributes:

`UUID.bytes`

The UUID as a 16-byte string (containing the six integer fields in big-endian byte order).

`UUID.bytes_le`

The UUID as a 16-byte string (with `time_low`, `time_mid`, and `time_hi_version` in little-endian byte order).

`UUID.fields`

A tuple of the six integer fields of the UUID, which are also available as six individual attributes and two derived attributes:

Field	Meaning
<code>time_low</code>	the first 32 bits of the UUID
<code>time_mid</code>	the next 16 bits of the UUID
<code>time_hi_version</code>	the next 16 bits of the UUID
<code>clock_seq_hi_variant</code>	the next 8 bits of the UUID
<code>clock_seq_low</code>	the next 8 bits of the UUID
<code>node</code>	the last 48 bits of the UUID
<code>time</code>	the 60-bit timestamp
<code>clock_seq</code>	the 14-bit sequence number

### `UUID.hex`

The UUID as a 32-character hexadecimal string.

### `UUID.int`

The UUID as a 128-bit integer.

### `UUID.urn`

The UUID as a URN as specified in RFC 4122.

### `UUID.variant`

The UUID variant, which determines the internal layout of the UUID. This will be one of the integer constants `RESERVED_NCS`, `RFC_4122`, `RESERVED_MICROSOFT`, or `RESERVED_FUTURE`.

### `UUID.version`

The UUID version number (1 through 5, meaningful only when the variant is `RFC_4122`).

The `uuid` module defines the following functions:

#### `uuid.getnode()`

Get the hardware address as a 48-bit positive integer. The first time this runs, it may launch a separate program, which could be quite slow. If all attempts to obtain the hardware address fail, we choose a random 48-bit number with its eighth bit set to 1 as recommended in RFC 4122. “Hardware address” means the MAC address of a network interface, and on a machine with multiple network interfaces the MAC address of any one of them may be returned.

#### `uuid.uuid1([node[, clock_seq]])`

Generate a UUID from a host ID, sequence number, and the current time. If `node` is not given, `getnode()` is used to obtain the hardware address. If `clock_seq` is given, it is used as the sequence number; otherwise a random 14-bit sequence number is chosen.

#### `uuid.uuid3(namespace, name)`

Generate a UUID based on the MD5 hash of a namespace identifier (which is a UUID) and a name (which is a string).

#### `uuid.uuid4()`

Generate a random UUID.

#### `uuid.uuid5(namespace, name)`

Generate a UUID based on the SHA-1 hash of a namespace identifier (which is a UUID) and a name (which is a string).

The `uuid` module defines the following namespace identifiers for use with `uuid3()` or `uuid5()`.

#### `uuid.NAMESPACE_DNS`

When this namespace is specified, the `name` string is a fully-qualified domain name.

#### `uuid.NAMESPACE_URL`

When this namespace is specified, the `name` string is a URL.

#### `uuid.NAMESPACE_OID`

When this namespace is specified, the `name` string is an ISO OID.

#### `uuid.NAMESPACE_X500`

When this namespace is specified, the `name` string is an X.500 DN in DER or a text output format.

The `uuid` module defines the following constants for the possible values of the `variant` attribute:

#### `uuid.RESERVED_NCS`

Reserved for NCS compatibility.

#### `uuid.RFC_4122`

Specifies the UUID layout given in [RFC 4122](#).

`uuid.RESERVED_MICROSOFT`  
Reserved for Microsoft compatibility.

`uuid.RESERVED_FUTURE`  
Reserved for future definition.

**See Also:**

**RFC 4122 - A Universally Unique Identifier (UUID) URN Namespace** This specification defines a Uniform Resource Name namespace for UUIDs, the internal format of UUIDs, and methods of generating UUIDs.

## 20.15.1 Example

Here are some examples of typical usage of the `uuid` module:

```
>>> import uuid

>>> # make a UUID based on the host ID and current time
>>> uuid.uuid1()
UUID('a8098c1a-f86e-11da-bd1a-00112444be1e')

>>> # make a UUID using an MD5 hash of a namespace UUID and a name
>>> uuid.uuid3(uuid.NAMESPACE_DNS, 'python.org')
UUID('6fa459ea-ee8a-3ca4-894e-db77e160355e')

>>> # make a random UUID
>>> uuid.uuid4()
UUID('16fd2706-8baf-433b-82eb-8c7fada847da')

>>> # make a UUID using a SHA-1 hash of a namespace UUID and a name
>>> uuid.uuid5(uuid.NAMESPACE_DNS, 'python.org')
UUID('886313e1-3b8a-5372-9b90-0c9aee199e5d')

>>> # make a UUID from a string of hex digits (braces and hyphens ignored)
>>> x = uuid.UUID('{00010203-0405-0607-0809-0a0b0c0d0e0f}')

>>> # convert a UUID to a string of hex digits in standard form
>>> str(x)
'00010203-0405-0607-0809-0a0b0c0d0e0f'

>>> # get the raw 16 bytes of the UUID
>>> x.bytes
'\x00\x01\x02\x03\x04\x05\x06\x07\x08\t\n\x0b\x0c\r\x0e\x0f'

>>> # make a UUID from a 16-byte string
>>> uuid.UUID(bytes=x.bytes)
UUID('00010203-0405-0607-0809-0a0b0c0d0e0f')
```

## 20.16 urlparse — Parse URLs into components

**Note:** The `urlparse` module is renamed to `urllib.parse` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

Source code: [Lib/urllibparse.py](#)

---

This module defines a standard interface to break Uniform Resource Locator (URL) strings up in components (addressing scheme, network location, path etc.), to combine the components back into a URL string, and to convert a “relative URL” to an absolute URL given a “base URL.”

The module has been designed to match the Internet RFC on Relative Uniform Resource Locators. It supports the following URL schemes: `file`, `ftp`, `gopher`, `hdl`, `http`, `https`, `imap`, `mailto`, `mms`, `news`, `nntp`, `prospero`, `rsync`, `rtsp`, `rtspu`, `sftp`, `shttp`, `sip`, `sips`, `snews`, `svn`, `svn+ssh`, `telnet`, `wais`. New in version 2.5: Support for the `sftp` and `sips` schemes. The `urllibparse` module defines the following functions:

`urllibparse.urlparse(urlstring[, scheme[, allow_fragments]])`

Parse a URL into six components, returning a 6-tuple. This corresponds to the general structure of a URL: `scheme://netloc/path;parameters?query#fragment`. Each tuple item is a string, possibly empty. The components are not broken up in smaller parts (for example, the network location is a single string), and `%` escapes are not expanded. The delimiters as shown above are not part of the result, except for a leading slash in the `path` component, which is retained if present. For example:

```
>>> from urllibparse import urlparse
>>> o = urlparse('http://www.cwi.nl:80/%7Eguido/Python.html')
>>> o
ParseResult(scheme='http', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> o.scheme
'http'
>>> o.port
80
>>> o.geturl()
'http://www.cwi.nl:80/%7Eguido/Python.html'
```

Following the syntax specifications in [RFC 1808](#), `urllibparse` recognizes a netloc only if it is properly introduced by `://`. Otherwise the input is presumed to be a relative URL and thus to start with a path component.

```
>>> from urllibparse import urlparse
>>> urlparse('//www.cwi.nl:80/%7Eguido/Python.html')
ParseResult(scheme='', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> urlparse('www.cwi.nl:80/%7Eguido/Python.html')
ParseResult(scheme='', netloc='', path='www.cwi.nl:80/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> urlparse('help/Python.html')
ParseResult(scheme='', netloc='', path='help/Python.html', params='',
            query='', fragment='')
```

If the `scheme` argument is specified, it gives the default addressing scheme, to be used only if the URL does not specify one. The default value for this argument is the empty string.

If the `allow_fragments` argument is false, fragment identifiers are not allowed, even if the URL’s addressing scheme normally does support them. The default value for this argument is `True`.

The return value is actually an instance of a subclass of `tuple`. This class has the following additional read-only convenience attributes:

Attribute	Index	Value	Value if not present
scheme	0	URL scheme specifier	empty string
netloc	1	Network location part	empty string
path	2	Hierarchical path	empty string
params	3	Parameters for last path element	empty string
query	4	Query component	empty string
fragment	5	Fragment identifier	empty string
username		User name	None
password		Password	None
hostname		Host name (lower case)	None
port		Port number as integer, if present	None

See section *Results of `urlparse()` and `urlsplit()`* for more information on the result object. Changed in version 2.5: Added attributes to return value. Changed in version 2.7: Added IPv6 URL parsing capabilities.

`urlparse.parse_qs(qs[, keep_blank_values[, strict_parsing ] ])`

Parse a query string given as a string argument (data of type *application/x-www-form-urlencoded*). Data are returned as a dictionary. The dictionary keys are the unique query variable names and the values are lists of values for each name.

The optional argument *keep\_blank\_values* is a flag indicating whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.

The optional argument *strict\_parsing* is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a `ValueError` exception.

Use the `urllib.urlencode()` function to convert such dictionaries into query strings. New in version 2.6: Copied from the `cgi` module.

`urlparse.parse_qs1(qs[, keep_blank_values[, strict_parsing ] ])`

Parse a query string given as a string argument (data of type *application/x-www-form-urlencoded*). Data are returned as a list of name, value pairs.

The optional argument *keep\_blank\_values* is a flag indicating whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.

The optional argument *strict\_parsing* is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a `ValueError` exception.

Use the `urllib.urlencode()` function to convert such lists of pairs into query strings. New in version 2.6: Copied from the `cgi` module.

`urlparse.urlunparse(parts)`

Construct a URL from a tuple as returned by `urlparse()`. The *parts* argument can be any six-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a ? with an empty query; the RFC states that these are equivalent).

`urlparse.urlsplit(urlstring[, scheme[, allow_fragments ] ])`

This is similar to `urlparse()`, but does not split the params from the URL. This should generally be used instead of `urlparse()` if the more recent URL syntax allowing parameters to be applied to each segment of the *path* portion of the URL (see [RFC 2396](#)) is wanted. A separate function is needed to separate the path segments and parameters. This function returns a 5-tuple: (addressing scheme, network location, path, query, fragment identifier).

The return value is actually an instance of a subclass of `tuple`. This class has the following additional read-only convenience attributes:

Attribute	Index	Value	Value if not present
scheme	0	URL scheme specifier	empty string
netloc	1	Network location part	empty string
path	2	Hierarchical path	empty string
query	3	Query component	empty string
fragment	4	Fragment identifier	empty string
username		User name	None
password		Password	None
hostname		Host name (lower case)	None
port		Port number as integer, if present	None

See section *Results of `urlparse()` and `urlsplit()`* for more information on the result object. New in version 2.2.Changed in version 2.5: Added attributes to return value.

`urlparse.urlunsplit` (*parts*)

Combine the elements of a tuple as returned by `urlsplit()` into a complete URL as a string. The *parts* argument can be any five-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a `?` with an empty query; the RFC states that these are equivalent). New in version 2.2.

`urlparse.urljoin` (*base*, *url*[, *allow\_fragments* ])

Construct a full (“absolute”) URL by combining a “base URL” (*base*) with another URL (*url*). Informally, this uses components of the base URL, in particular the addressing scheme, the network location and (part of) the path, to provide missing components in the relative URL. For example:

```
>>> from urlparse import urljoin
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html', 'FAQ.html')
'http://www.cwi.nl/%7Eguido/FAQ.html'
```

The *allow\_fragments* argument has the same meaning and default as for `urlparse()`.

---

**Note:** If *url* is an absolute URL (that is, starting with `//` or `scheme://`), the *url*'s host name and/or scheme will be present in the result. For example:

---

```
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html',
...         '//www.python.org/%7Eguido')
'http://www.python.org/%7Eguido'
```

If you do not want that behavior, preprocess the *url* with `urlsplit()` and `urlunsplit()`, removing possible *scheme* and *netloc* parts.

`urlparse.urldefrag` (*url*)

If *url* contains a fragment identifier, returns a modified version of *url* with no fragment identifier, and the fragment identifier as a separate string. If there is no fragment identifier in *url*, returns *url* unmodified and an empty string.

**See Also:**

**RFC 3986 - Uniform Resource Identifiers** This is the current standard (STD66). Any changes to `urlparse` module should conform to this. Certain deviations could be observed, which are mostly due backward compatibility purposes and for certain de-facto parsing requirements as commonly observed in major browsers.

**RFC 2732 - Format for Literal IPv6 Addresses in URL's.** This specifies the parsing requirements of IPv6 URLs.

**RFC 2396 - Uniform Resource Identifiers (URI): Generic Syntax** Document describing the generic syntactic requirements for both Uniform Resource Names (URNs) and Uniform Resource Locators (URLs).

**RFC 2368 - The mailto URL scheme.** Parsing requirements for mailto url schemes.

**RFC 1808 - Relative Uniform Resource Locators** This Request For Comments includes the rules for joining an absolute and a relative URL, including a fair number of “Abnormal Examples” which govern the treatment of border cases.

**RFC 1738 - Uniform Resource Locators (URL)** This specifies the formal syntax and semantics of absolute URLs.

### 20.16.1 Results of `urlparse()` and `urlsplit()`

The result objects from the `urlparse()` and `urlsplit()` functions are subclasses of the `tuple` type. These subclasses add the attributes described in those functions, as well as provide an additional method:

`ParseResult.geturl()`

Return the re-combined version of the original URL as a string. This may differ from the original URL in that the scheme will always be normalized to lower case and empty components may be dropped. Specifically, empty parameters, queries, and fragment identifiers will be removed.

The result of this method is a fixpoint if passed back through the original parsing function:

```
>>> import urlparse
>>> url = 'HTTP://www.Python.org/doc/#'

>>> r1 = urlparse.urlsplit(url)
>>> r1.geturl()
'http://www.Python.org/doc/'

>>> r2 = urlparse.urlsplit(r1.geturl())
>>> r2.geturl()
'http://www.Python.org/doc/'
```

New in version 2.5.

The following classes provide the implementations of the parse results:

**class** `urlparse.BaseResult`

Base class for the concrete result classes. This provides most of the attribute definitions. It does not provide a `geturl()` method. It is derived from `tuple`, but does not override the `__init__()` or `__new__()` methods.

**class** `urlparse.ParseResult` (*scheme, netloc, path, params, query, fragment*)

Concrete class for `urlparse()` results. The `__new__()` method is overridden to support checking that the right number of arguments are passed.

**class** `urlparse.SplitResult` (*scheme, netloc, path, query, fragment*)

Concrete class for `urlsplit()` results. The `__new__()` method is overridden to support checking that the right number of arguments are passed.

## 20.17 SocketServer — A framework for network servers

**Note:** The `SocketServer` module has been renamed to `socketserver` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

**Source code:** [Lib/SocketServer.py](#)

The `SocketServer` module simplifies the task of writing network servers.

There are four basic server classes: `TCPServer` uses the Internet TCP protocol, which provides for continuous streams of data between the client and server. `UDPServer` uses datagrams, which are discrete packets of information that may arrive out of order or be lost while in transit. The more infrequently used `UnixStreamServer` and `UnixDatagramServer` classes are similar, but use Unix domain sockets; they're not available on non-Unix platforms. For more details on network programming, consult a book such as W. Richard Steven's *UNIX Network Programming* or Ralph Davis's *Win32 Network Programming*.

These four classes process requests *synchronously*; each request must be completed before the next request can be started. This isn't suitable if each request takes a long time to complete, because it requires a lot of computation, or because it returns a lot of data which the client is slow to process. The solution is to create a separate process or thread to handle each request; the `ForkingMixIn` and `ThreadingMixIn` mix-in classes can be used to support asynchronous behaviour.

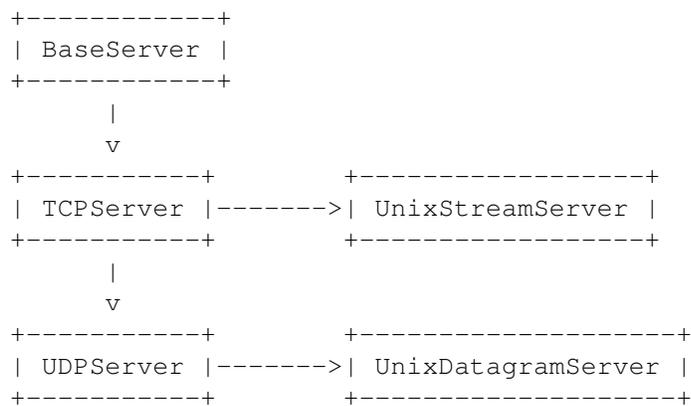
Creating a server requires several steps. First, you must create a request handler class by subclassing the `BaseRequestHandler` class and overriding its `handle()` method; this method will process incoming requests. Second, you must instantiate one of the server classes, passing it the server's address and the request handler class. Finally, call the `handle_request()` or `serve_forever()` method of the server object to process one or many requests.

When inheriting from `ThreadingMixIn` for threaded connection behavior, you should explicitly declare how you want your threads to behave on an abrupt shutdown. The `ThreadingMixIn` class defines an attribute `daemon_threads`, which indicates whether or not the server should wait for thread termination. You should set the flag explicitly if you would like threads to behave autonomously; the default is `False`, meaning that Python will not exit until all threads created by `ThreadingMixIn` have exited.

Server classes have the same external methods and attributes, no matter what network protocol they use.

### 20.17.1 Server Creation Notes

There are five classes in an inheritance diagram, four of which represent synchronous servers of four types:



Note that `UnixDatagramServer` derives from `UDPServer`, not from `UnixStreamServer` — the only difference between an IP and a Unix stream server is the address family, which is simply repeated in both Unix server classes.

Forking and threading versions of each type of server can be created using the `ForkingMixIn` and `ThreadingMixIn` mix-in classes. For instance, a threading UDP server class is created as follows:

```
class ThreadingUDPServer(ThreadingMixIn, UDPServer): pass
```

The mix-in class must come first, since it overrides a method defined in `UDPServer`. Setting the various attributes also change the behavior of the underlying server mechanism.

To implement a service, you must derive a class from `BaseRequestHandler` and redefine its `handle()` method. You can then run various versions of the service by combining one of the server classes with your request handler class. The request handler class must be different for datagram or stream services. This can be hidden by using the handler subclasses `StreamRequestHandler` or `DatagramRequestHandler`.

Of course, you still have to use your head! For instance, it makes no sense to use a forking server if the service contains state in memory that can be modified by different requests, since the modifications in the child process would never reach the initial state kept in the parent process and passed to each child. In this case, you can use a threading server, but you will probably have to use locks to protect the integrity of the shared data.

On the other hand, if you are building an HTTP server where all data is stored externally (for instance, in the file system), a synchronous class will essentially render the service “deaf” while one request is being handled – which may be for a very long time if a client is slow to receive all the data it has requested. Here a threading or forking server is appropriate.

In some cases, it may be appropriate to process part of a request synchronously, but to finish processing in a forked child depending on the request data. This can be implemented by using a synchronous server and doing an explicit fork in the request handler class `handle()` method.

Another approach to handling multiple simultaneous requests in an environment that supports neither threads nor `fork()` (or where these are too expensive or inappropriate for the service) is to maintain an explicit table of partially finished requests and to use `select()` to decide which request to work on next (or whether to handle a new incoming request). This is particularly important for stream services where each client can potentially be connected for a long time (if threads or subprocesses cannot be used). See [`asyncore`](#) for another way to manage this.

## 20.17.2 Server Objects

### `class SocketServer.BaseServer`

This is the superclass of all Server objects in the module. It defines the interface, given below, but does not implement most of the methods, which is done in subclasses.

#### `BaseServer.fileno()`

Return an integer file descriptor for the socket on which the server is listening. This function is most commonly passed to `select.select()`, to allow monitoring multiple servers in the same process.

#### `BaseServer.handle_request()`

Process a single request. This function calls the following methods in order: `get_request()`, `verify_request()`, and `process_request()`. If the user-provided `handle()` method of the handler class raises an exception, the server’s `handle_error()` method will be called. If no request is received within `self.timeout` seconds, `handle_timeout()` will be called and `handle_request()` will return.

#### `BaseServer.serve_forever(poll_interval=0.5)`

Handle requests until an explicit `shutdown()` request. Poll for shutdown every `poll_interval` seconds. Ignores `self.timeout`. If you need to do periodic tasks, do them in another thread.

#### `BaseServer.shutdown()`

Tell the `serve_forever()` loop to stop and wait until it does. New in version 2.6.

#### `BaseServer.address_family`

The family of protocols to which the server’s socket belongs. Common examples are `socket.AF_INET` and `socket.AF_UNIX`.

#### `BaseServer.RequestHandlerClass`

The user-provided request handler class; an instance of this class is created for each request.

### `BaseServer.server_address`

The address on which the server is listening. The format of addresses varies depending on the protocol family; see the documentation for the `socket` module for details. For Internet protocols, this is a tuple containing a string giving the address, and an integer port number: `('127.0.0.1', 80)`, for example.

### `BaseServer.socket`

The socket object on which the server will listen for incoming requests.

The server classes support the following class variables:

### `BaseServer.allow_reuse_address`

Whether the server will allow the reuse of an address. This defaults to `False`, and can be set in subclasses to change the policy.

### `BaseServer.request_queue_size`

The size of the request queue. If it takes a long time to process a single request, any requests that arrive while the server is busy are placed into a queue, up to `request_queue_size` requests. Once the queue is full, further requests from clients will get a “Connection denied” error. The default value is usually 5, but this can be overridden by subclasses.

### `BaseServer.socket_type`

The type of socket used by the server; `socket.SOCK_STREAM` and `socket.SOCK_DGRAM` are two common values.

### `BaseServer.timeout`

Timeout duration, measured in seconds, or `None` if no timeout is desired. If `handle_request()` receives no incoming requests within the timeout period, the `handle_timeout()` method is called.

There are various server methods that can be overridden by subclasses of base server classes like `TCPServer`; these methods aren't useful to external users of the server object.

### `BaseServer.finish_request()`

Actually processes the request by instantiating `RequestHandlerClass` and calling its `handle()` method.

### `BaseServer.get_request()`

Must accept a request from the socket, and return a 2-tuple containing the *new* socket object to be used to communicate with the client, and the client's address.

### `BaseServer.handle_error(request, client_address)`

This function is called if the `RequestHandlerClass`'s `handle()` method raises an exception. The default action is to print the traceback to standard output and continue handling further requests.

### `BaseServer.handle_timeout()`

This function is called when the `timeout` attribute has been set to a value other than `None` and the timeout period has passed with no requests being received. The default action for forking servers is to collect the status of any child processes that have exited, while in threading servers this method does nothing.

### `BaseServer.process_request(request, client_address)`

Calls `finish_request()` to create an instance of the `RequestHandlerClass`. If desired, this function can create a new process or thread to handle the request; the `ForkingMixIn` and `ThreadingMixIn` classes do this.

### `BaseServer.server_activate()`

Called by the server's constructor to activate the server. The default behavior just `listen()`s to the server's socket. May be overridden.

### `BaseServer.server_bind()`

Called by the server's constructor to bind the socket to the desired address. May be overridden.

### `BaseServer.verify_request(request, client_address)`

Must return a Boolean value; if the value is `True`, the request will be processed, and if it's `False`, the re-

quest will be denied. This function can be overridden to implement access controls for a server. The default implementation always returns `True`.

### 20.17.3 RequestHandler Objects

The request handler class must define a new `handle()` method, and can override any of the following methods. A new instance is created for each request.

`RequestHandler.finish()`

Called after the `handle()` method to perform any clean-up actions required. The default implementation does nothing. If `setup()` or `handle()` raise an exception, this function will not be called.

`RequestHandler.handle()`

This function must do all the work required to service a request. The default implementation does nothing. Several instance attributes are available to it; the request is available as `self.request`; the client address as `self.client_address`; and the server instance as `self.server`, in case it needs access to per-server information.

The type of `self.request` is different for datagram or stream services. For stream services, `self.request` is a socket object; for datagram services, `self.request` is a pair of string and socket. However, this can be hidden by using the request handler subclasses `StreamRequestHandler` or `DatagramRequestHandler`, which override the `setup()` and `finish()` methods, and provide `self.rfile` and `self.wfile` attributes. `self.rfile` and `self.wfile` can be read or written, respectively, to get the request data or return data to the client.

`RequestHandler.setup()`

Called before the `handle()` method to perform any initialization actions required. The default implementation does nothing.

### 20.17.4 Examples

#### SocketServer.TCPServer Example

This is the server side:

```
import SocketServer

class MyTCPHandler(SocketServer.BaseRequestHandler):
    """
    The RequestHandler class for our server.

    It is instantiated once per connection to the server, and must
    override the handle() method to implement communication to the
    client.
    """

    def handle(self):
        # self.request is the TCP socket connected to the client
        self.data = self.request.recv(1024).strip()
        print "{} wrote:".format(self.client_address[0])
        print self.data
        # just send back the same data, but upper-cased
        self.request.sendall(self.data.upper())

if __name__ == "__main__":
```

```
HOST, PORT = "localhost", 9999

# Create the server, binding to localhost on port 9999
server = SocketServer.TCPServer((HOST, PORT), MyTCPHandler)

# Activate the server; this will keep running until you
# interrupt the program with Ctrl-C
server.serve_forever()
```

An alternative request handler class that makes use of streams (file-like objects that simplify communication by providing the standard file interface):

```
class MyTCPHandler(SocketServer.StreamRequestHandler):

    def handle(self):
        # self.rfile is a file-like object created by the handler;
        # we can now use e.g. readline() instead of raw recv() calls
        self.data = self.rfile.readline().strip()
        print "{} wrote:".format(self.client_address[0])
        print self.data
        # Likewise, self.wfile is a file-like object used to write back
        # to the client
        self.wfile.write(self.data.upper())
```

The difference is that the `readline()` call in the second handler will call `recv()` multiple times until it encounters a newline character, while the single `recv()` call in the first handler will just return what has been sent from the client in one `sendall()` call.

This is the client side:

```
import socket
import sys

HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:])

# Create a socket (SOCK_STREAM means a TCP socket)
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

try:
    # Connect to server and send data
    sock.connect((HOST, PORT))
    sock.sendall(data + "\n")

    # Receive data from the server and shut down
    received = sock.recv(1024)
finally:
    sock.close()

print "Sent: {}".format(data)
print "Received: {}".format(received)
```

The output of the example should look something like this:

Server:

```
$ python TCPServer.py
127.0.0.1 wrote:
```

```
hello world with TCP
127.0.0.1 wrote:
python is nice
```

Client:

```
$ python TCPClient.py hello world with TCP
Sent:      hello world with TCP
Received:  HELLO WORLD WITH TCP
$ python TCPClient.py python is nice
Sent:      python is nice
Received:  PYTHON IS NICE
```

### SocketServer.UDPServer Example

This is the server side:

```
import SocketServer

class MyUDPHandler(SocketServer.BaseRequestHandler):
    """
    This class works similar to the TCP handler class, except that
    self.request consists of a pair of data and client socket, and since
    there is no connection the client address must be given explicitly
    when sending data back via sendto().
    """

    def handle(self):
        data = self.request[0].strip()
        socket = self.request[1]
        print "{} wrote:".format(self.client_address[0])
        print data
        socket.sendto(data.upper(), self.client_address)

if __name__ == "__main__":
    HOST, PORT = "localhost", 9999
    server = SocketServer.UDPServer((HOST, PORT), MyUDPHandler)
    server.serve_forever()
```

This is the client side:

```
import socket
import sys

HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:])

# SOCK_DGRAM is the socket type to use for UDP sockets
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

# As you can see, there is no connect() call; UDP has no connections.
# Instead, data is directly sent to the recipient via sendto().
sock.sendto(data + "\n", (HOST, PORT))
received = sock.recv(1024)
```

```
print "Sent:      {}".format(data)
print "Received: {}".format(received)
```

The output of the example should look exactly like for the TCP server example.

### Asynchronous Mixins

To build asynchronous handlers, use the `ThreadingMixin` and `ForkingMixin` classes.

An example for the `ThreadingMixin` class:

```
import socket
import threading
import SocketServer

class ThreadedTCPRequestHandler(SocketServer.BaseRequestHandler):

    def handle(self):
        data = self.request.recv(1024)
        cur_thread = threading.current_thread()
        response = "{}: {}".format(cur_thread.name, data)
        self.request.sendall(response)

class ThreadedTCPServer(SocketServer.ThreadingMixin, SocketServer.TCPServer):
    pass

def client(ip, port, message):
    sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    sock.connect((ip, port))
    try:
        sock.sendall(message)
        response = sock.recv(1024)
        print "Received: {}".format(response)
    finally:
        sock.close()

if __name__ == "__main__":
    # Port 0 means to select an arbitrary unused port
    HOST, PORT = "localhost", 0

    server = ThreadedTCPServer((HOST, PORT), ThreadedTCPRequestHandler)
    ip, port = server.server_address

    # Start a thread with the server -- that thread will then start one
    # more thread for each request
    server_thread = threading.Thread(target=server.serve_forever)
    # Exit the server thread when the main thread terminates
    server_thread.daemon = True
    server_thread.start()
    print "Server loop running in thread:", server_thread.name

    client(ip, port, "Hello World 1")
    client(ip, port, "Hello World 2")
    client(ip, port, "Hello World 3")
```

```
server.shutdown()
```

The output of the example should look something like this:

```
$ python ThreadedTCPServer.py
Server loop running in thread: Thread-1
Received: Thread-2: Hello World 1
Received: Thread-3: Hello World 2
Received: Thread-4: Hello World 3
```

The `ForkingMixIn` class is used in the same way, except that the server will spawn a new process for each request.

## 20.18 BaseHTTPServer — Basic HTTP server

**Note:** The `BaseHTTPServer` module has been merged into `http.server` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

**Source code:** [Lib/BaseHTTPServer.py](#)

This module defines two classes for implementing HTTP servers (Web servers). Usually, this module isn't used directly, but is used as a basis for building functioning Web servers. See the `SimpleHTTPServer` and `CGIHTTPServer` modules.

The first class, `HTTPServer`, is a `SocketServer.TCPServer` subclass, and therefore implements the `SocketServer.BaseServer` interface. It creates and listens at the HTTP socket, dispatching the requests to a handler. Code to create and run the server looks like this:

```
def run(server_class=BaseHTTPServer.HTTPServer,
        handler_class=BaseHTTPServer.BaseHTTPRequestHandler):
    server_address = ('', 8000)
    httpd = server_class(server_address, handler_class)
    httpd.serve_forever()
```

**class** `BaseHTTPServer.HTTPServer` (*server\_address, RequestHandlerClass*)

This class builds on the `TCPServer` class by storing the server address as instance variables named `server_name` and `server_port`. The server is accessible by the handler, typically through the handler's `server` instance variable.

**class** `BaseHTTPServer.BaseHTTPRequestHandler` (*request, client\_address, server*)

This class is used to handle the HTTP requests that arrive at the server. By itself, it cannot respond to any actual HTTP requests; it must be subclassed to handle each request method (e.g. GET or POST). `BaseHTTPRequestHandler` provides a number of class and instance variables, and methods for use by subclasses.

The handler will parse the request and the headers, then call a method specific to the request type. The method name is constructed from the request. For example, for the request method SPAM, the `do_SPAM()` method will be called with no arguments. All of the relevant information is stored in instance variables of the handler. Subclasses should not need to override or extend the `__init__()` method.

`BaseHTTPRequestHandler` has the following instance variables:

**client\_address**

Contains a tuple of the form (`host`, `port`) referring to the client's address.

**server**

Contains the server instance.

**command**

Contains the command (request type). For example, 'GET'.

**path**

Contains the request path.

**request\_version**

Contains the version string from the request. For example, 'HTTP/1.0'.

**headers**

Holds an instance of the class specified by the `MessageClass` class variable. This instance parses and manages the headers in the HTTP request.

**rfile**

Contains an input stream, positioned at the start of the optional input data.

**wfile**

Contains the output stream for writing a response back to the client. Proper adherence to the HTTP protocol must be used when writing to this stream.

`BaseHTTPRequestHandler` has the following class variables:

**server\_version**

Specifies the server software version. You may want to override this. The format is multiple whitespace-separated strings, where each string is of the form `name[/version]`. For example, 'BaseHTTP/0.2'.

**sys\_version**

Contains the Python system version, in a form usable by the `version_string` method and the `server_version` class variable. For example, 'Python/1.4'.

**error\_message\_format**

Specifies a format string for building an error response to the client. It uses parenthesized, keyed format specifiers, so the format operand must be a dictionary. The `code` key should be an integer, specifying the numeric HTTP error code value. `message` should be a string containing a (detailed) error message of what occurred, and `explain` should be an explanation of the error code number. Default `message` and `explain` values can be found in the `responses` class variable.

**error\_content\_type**

Specifies the Content-Type HTTP header of error responses sent to the client. The default value is 'text/html'. New in version 2.6: Previously, the content type was always 'text/html'.

**protocol\_version**

This specifies the HTTP protocol version used in responses. If set to 'HTTP/1.1', the server will permit HTTP persistent connections; however, your server *must* then include an accurate `Content-Length` header (using `send_header()`) in all of its responses to clients. For backwards compatibility, the setting defaults to 'HTTP/1.0'.

**MessageClass**

Specifies a `rfc822.Message`-like class to parse HTTP headers. Typically, this is not overridden, and it defaults to `mimetools.Message`.

**responses**

This variable contains a mapping of error code integers to two-element tuples containing a short and long message. For example, `{code: (shortmessage, longmessage)}`. The `shortmessage` is usually used as the `message` key in an error response, and `longmessage` as the `explain` key (see the `error_message_format` class variable).

A `BaseHTTPRequestHandler` instance has the following methods:

**handle ()**

Calls `handle_one_request ()` once (or, if persistent connections are enabled, multiple times) to handle incoming HTTP requests. You should never need to override it; instead, implement appropriate `do_* ()` methods.

**handle\_one\_request ()**

This method will parse and dispatch the request to the appropriate `do_* ()` method. You should never need to override it.

**send\_error (code[, message ])**

Sends and logs a complete error reply to the client. The numeric *code* specifies the HTTP error code, with *message* as optional, more specific text. A complete set of headers is sent, followed by text composed using the `error_message_format` class variable.

**send\_response (code[, message ])**

Sends a response header and logs the accepted request. The HTTP response line is sent, followed by *Server* and *Date* headers. The values for these two headers are picked up from the `version_string ()` and `date_time_string ()` methods, respectively.

**send\_header (keyword, value)**

Writes a specific HTTP header to the output stream. *keyword* should specify the header keyword, with *value* specifying its value.

**end\_headers ()**

Sends a blank line, indicating the end of the HTTP headers in the response.

**log\_request ([code[, size ]])**

Logs an accepted (successful) request. *code* should specify the numeric HTTP code associated with the response. If a size of the response is available, then it should be passed as the *size* parameter.

**log\_error (...)**

Logs an error when a request cannot be fulfilled. By default, it passes the message to `log_message ()`, so it takes the same arguments (*format* and additional values).

**log\_message (format, ...)**

Logs an arbitrary message to `sys.stderr`. This is typically overridden to create custom error logging mechanisms. The *format* argument is a standard printf-style format string, where the additional arguments to `log_message ()` are applied as inputs to the formatting. The client ip address and current date and time are prefixed to every message logged.

**version\_string ()**

Returns the server software's version string. This is a combination of the `server_version` and `sys_version` class variables.

**date\_time\_string ([timestamp ])**

Returns the date and time given by *timestamp* (which must be in the format returned by `time.time ()`), formatted for a message header. If *timestamp* is omitted, it uses the current date and time.

The result looks like 'Sun, 06 Nov 1994 08:49:37 GMT'. New in version 2.5: The *timestamp* parameter.

**log\_date\_time\_string ()**

Returns the current date and time, formatted for logging.

**address\_string ()**

Returns the client address, formatted for logging. A name lookup is performed on the client's IP address.

## 20.18.1 More examples

To create a server that doesn't run forever, but until some condition is fulfilled:

```
def run_while_true(server_class=BaseHTTPServer.HTTPServer,
                  handler_class=BaseHTTPServer.BaseHTTPRequestHandler):
    """
    This assumes that keep_running() is a function of no arguments which
    is tested initially and after each request. If its return value
    is true, the server continues.
    """
    server_address = ('', 8000)
    httpd = server_class(server_address, handler_class)
    while keep_running():
        httpd.handle_request()
```

### See Also:

**Module `CGIHTTPServer`** Extended request handler that supports CGI scripts.

**Module `SimpleHTTPServer`** Basic request handler that limits response to files actually under the document root.

## 20.19 SimpleHTTPServer — Simple HTTP request handler

---

**Note:** The `SimpleHTTPServer` module has been merged into `http.server` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

The `SimpleHTTPServer` module defines a single class, `SimpleHTTPRequestHandler`, which is interface-compatible with `BaseHTTPServer.BaseHTTPRequestHandler`.

The `SimpleHTTPServer` module defines the following class:

**class** `SimpleHTTPServer.SimpleHTTPRequestHandler` (*request, client\_address, server*)

This class serves files from the current directory and below, directly mapping the directory structure to HTTP requests.

A lot of the work, such as parsing the request, is done by the base class `BaseHTTPServer.BaseHTTPRequestHandler`. This class implements the `do_GET()` and `do_HEAD()` functions.

The following are defined as class-level attributes of `SimpleHTTPRequestHandler`:

### **server\_version**

This will be `"SimpleHTTP/" + __version__`, where `__version__` is defined at the module level.

### **extensions\_map**

A dictionary mapping suffixes into MIME types. The default is signified by an empty string, and is considered to be `application/octet-stream`. The mapping is used case-insensitively, and so should contain only lower-cased keys.

The `SimpleHTTPRequestHandler` class defines the following methods:

### **do\_HEAD()**

This method serves the 'HEAD' request type: it sends the headers it would send for the equivalent GET request. See the `do_GET()` method for a more complete explanation of the possible headers.

### **do\_GET()**

The request is mapped to a local file by interpreting the request as a path relative to the current working directory.

If the request was mapped to a directory, the directory is checked for a file named `index.html` or `index.htm` (in that order). If found, the file's contents are returned; otherwise a directory listing is generated by calling the `list_directory()` method. This method uses `os.listdir()` to scan the directory, and returns a 404 error response if the `listdir()` fails.

If the request was mapped to a file, it is opened and the contents are returned. Any `IOError` exception in opening the requested file is mapped to a 404, 'File not found' error. Otherwise, the content type is guessed by calling the `guess_type()` method, which in turn uses the `extensions_map` variable.

A 'Content-type:' header with the guessed content type is output, followed by a 'Content-Length:' header with the file's size and a 'Last-Modified:' header with the file's modification time.

Then follows a blank line signifying the end of the headers, and then the contents of the file are output. If the file's MIME type starts with `text/` the file is opened in text mode; otherwise binary mode is used.

The `test()` function in the `SimpleHTTPServer` module is an example which creates a server using the `SimpleHTTPRequestHandler` as the Handler. New in version 2.5: The 'Last-Modified' header.

The `SimpleHTTPServer` module can be used in the following manner in order to set up a very basic web server serving files relative to the current directory.

```
import SimpleHTTPServer
import SocketServer

PORT = 8000

Handler = SimpleHTTPServer.SimpleHTTPRequestHandler

httpd = SocketServer.TCPServer(("", PORT), Handler)

print "serving at port", PORT
httpd.serve_forever()
```

The `SimpleHTTPServer` module can also be invoked directly using the `-m` switch of the interpreter with a port number argument. Similar to the previous example, this serves the files relative to the current directory.

```
python -m SimpleHTTPServer 8000
```

**See Also:**

**Module `BaseHTTPServer`** Base class implementation for Web server and request handler.

## 20.20 CGIHTTPServer — CGI-capable HTTP request handler

---

**Note:** The `CGIHTTPServer` module has been merged into `http.server` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

The `CGIHTTPServer` module defines a request-handler class, interface compatible with `BaseHTTPServer.BaseHTTPRequestHandler` and inherits behavior from `SimpleHTTPServer.SimpleHTTPRequestHandler` but can also run CGI scripts.

---

**Note:** This module can run CGI scripts on Unix and Windows systems.

---

**Note:** CGI scripts run by the `CGIHTTPRequestHandler` class cannot execute redirects (HTTP code 302), because code 200 (script output follows) is sent prior to execution of the CGI script. This pre-empts the status code.

---

The `CGIHTTPServer` module defines the following class:

**class** `CGIHTTPServer.CGIHTTPRequestHandler` (*request, client\_address, server*)

This class is used to serve either files or output of CGI scripts from the current directory and below. Note that mapping HTTP hierarchic structure to local directory structure is exactly as in `SimpleHTTPServer.SimpleHTTPRequestHandler`.

The class will however, run the CGI script, instead of serving it as a file, if it guesses it to be a CGI script. Only directory-based CGI are used — the other common server configuration is to treat special extensions as denoting CGI scripts.

The `do_GET()` and `do_HEAD()` functions are modified to run CGI scripts and serve the output, instead of serving files, if the request leads to somewhere below the `cgi_directories` path.

The `CGIHTTPRequestHandler` defines the following data member:

**`cgi_directories`**

This defaults to `['/cgi-bin', '/htbin']` and describes directories to treat as containing CGI scripts.

The `CGIHTTPRequestHandler` defines the following methods:

**`do_POST()`**

This method serves the 'POST' request type, only allowed for CGI scripts. Error 501, "Can only POST to CGI scripts", is output when trying to POST to a non-CGI url.

Note that CGI scripts will be run with UID of user nobody, for security reasons. Problems with the CGI script will be translated to error 403.

For example usage, see the implementation of the `test()` function.

**See Also:**

**Module `BaseHTTPServer`** Base class implementation for Web server and request handler.

## 20.21 `cookielib` — Cookie handling for HTTP clients

---

**Note:** The `cookielib` module has been renamed to `http.cookiejar` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

New in version 2.4. **Source code:** [Lib/cookiejar.py](#)

---

The `cookielib` module defines classes for automatic handling of HTTP cookies. It is useful for accessing web sites that require small pieces of data – *cookies* – to be set on the client machine by an HTTP response from a web server, and then returned to the server in later HTTP requests.

Both the regular Netscape cookie protocol and the protocol defined by

**RFC 2965** are handled. RFC 2965 handling is switched off by default.

**RFC 2109** cookies are parsed as Netscape cookies and subsequently treated either as Netscape or RFC 2965 cookies according to the 'policy' in effect. Note that the great majority of cookies on the Internet are Netscape cookies. `cookielib` attempts to follow the de-facto Netscape cookie protocol (which differs substantially from that set out

in the original Netscape specification), including taking note of the `max-age` and `port` cookie-attributes introduced with RFC 2965.

**Note:** The various named parameters found in `Set-Cookie` and `Set-Cookie2` headers (eg. `domain` and `expires`) are conventionally referred to as *attributes*. To distinguish them from Python attributes, the documentation for this module uses the term *cookie-attribute* instead.

The module defines the following exception:

**exception** `cookielib.LoadError`

Instances of `FileCookieJar` raise this exception on failure to load cookies from a file.

**Note:** For backwards-compatibility with Python 2.4 (which raised an `IOError`), `LoadError` is a subclass of `IOError`.

The following classes are provided:

**class** `cookielib.CookieJar` (*policy=None*)

*policy* is an object implementing the `CookiePolicy` interface.

The `CookieJar` class stores HTTP cookies. It extracts cookies from HTTP requests, and returns them in HTTP responses. `CookieJar` instances automatically expire contained cookies when necessary. Subclasses are also responsible for storing and retrieving cookies from a file or database.

**class** `cookielib.FileCookieJar` (*filename, delayload=None, policy=None*)

*policy* is an object implementing the `CookiePolicy` interface. For the other arguments, see the documentation for the corresponding attributes.

A `CookieJar` which can load cookies from, and perhaps save cookies to, a file on disk. Cookies are **NOT** loaded from the named file until either the `load()` or `revert()` method is called. Subclasses of this class are documented in section *FileCookieJar subclasses and co-operation with web browsers*.

**class** `cookielib.CookiePolicy`

This class is responsible for deciding whether each cookie should be accepted from / returned to the server.

**class** `cookielib.DefaultCookiePolicy` (*blocked\_domains=None, allowed\_domains=None, netscape=True, rfc2965=False, rfc2109\_as\_netscape=None, hide\_cookie2=False, strict\_domain=False, strict\_rfc2965\_unverifiable=True, strict\_ns\_unverifiable=False, strict\_ns\_domain=DefaultCookiePolicy.DomainLiberal, strict\_ns\_set\_initial\_dollar=False, strict\_ns\_set\_path=False*)

Constructor arguments should be passed as keyword arguments only. *blocked\_domains* is a sequence of domain names that we never accept cookies from, nor return cookies to. *allowed\_domains* if not `None`, this is a sequence of the only domains for which we accept and return cookies. For all other arguments, see the documentation for `CookiePolicy` and `DefaultCookiePolicy` objects.

`DefaultCookiePolicy` implements the standard accept / reject rules for Netscape and RFC 2965 cookies. By default, RFC 2109 cookies (ie. cookies received in a `Set-Cookie` header with a version cookie-attribute of 1) are treated according to the RFC 2965 rules. However, if RFC 2965 handling is turned off or `rfc2109_as_netscape` is `True`, RFC 2109 cookies are ‘downgraded’ by the `CookieJar` instance to Netscape cookies, by setting the `version` attribute of the `Cookie` instance to 0. `DefaultCookiePolicy` also provides some parameters to allow some fine-tuning of policy.

**class** `cookielib.Cookie`

This class represents Netscape, RFC 2109 and RFC 2965 cookies. It is not expected that users of `cookielib`

construct their own `Cookie` instances. Instead, if necessary, call `make_cookies()` on a `CookieJar` instance.

### See Also:

**Module `urllib2`** URL opening with automatic cookie handling.

**Module `Cookie`** HTTP cookie classes, principally useful for server-side code. The `cookielib` and `Cookie` modules do not depend on each other.

**[http://wp.netscape.com/newsref/std/cookie\\_spec.html](http://wp.netscape.com/newsref/std/cookie_spec.html)** The specification of the original Netscape cookie protocol. Though this is still the dominant protocol, the ‘Netscape cookie protocol’ implemented by all the major browsers (and `cookielib`) only bears a passing resemblance to the one sketched out in `cookie_spec.html`.

**RFC 2109 - HTTP State Management Mechanism** Obsoleted by RFC 2965. Uses `Set-Cookie` with `version=1`.

**RFC 2965 - HTTP State Management Mechanism** The Netscape protocol with the bugs fixed. Uses `Set-Cookie2` in place of `Set-Cookie`. Not widely used.

**<http://kristol.org/cookie/errata.html>** Unfinished errata to RFC 2965.

**RFC 2964** - Use of HTTP State Management

## 20.21.1 CookieJar and FileCookieJar Objects

`CookieJar` objects support the *iterator* protocol for iterating over contained `Cookie` objects.

`CookieJar` has the following methods:

`CookieJar.add_cookie_header(request)`

Add correct `Cookie` header to *request*.

If policy allows (ie. the `rfc2965` and `hide_cookie2` attributes of the `CookieJar`’s `CookiePolicy` instance are true and false respectively), the `Cookie2` header is also added when appropriate.

The *request* object (usually a `urllib2.Request` instance) must support the methods `get_full_url()`, `get_host()`, `get_type()`, `unverifiable()`, `get_origin_req_host()`, `has_header()`, `get_header()`, `header_items()`, and `add_unredirected_header()`, as documented by `urllib2`.

`CookieJar.extract_cookies(response, request)`

Extract cookies from HTTP *response* and store them in the `CookieJar`, where allowed by policy.

The `CookieJar` will look for allowable `Set-Cookie` and `Set-Cookie2` headers in the *response* argument, and store cookies as appropriate (subject to the `CookiePolicy.set_ok()` method’s approval).

The *response* object (usually the result of a call to `urllib2.urlopen()`, or similar) should support an `info()` method, which returns an object with a `getallmatchingheaders()` method (usually a `mimertools.Message` instance).

The *request* object (usually a `urllib2.Request` instance) must support the methods `get_full_url()`, `get_host()`, `unverifiable()`, and `get_origin_req_host()`, as documented by `urllib2`. The *request* is used to set default values for cookie-attributes as well as for checking that the cookie is allowed to be set.

`CookieJar.set_policy(policy)`

Set the `CookiePolicy` instance to be used.

`CookieJar.make_cookies(response, request)`

Return sequence of `Cookie` objects extracted from *response* object.

See the documentation for `extract_cookies()` for the interfaces required of the *response* and *request* arguments.

`CookieJar.set_cookie_if_ok(cookie, request)`

Set a `Cookie` if policy says it's OK to do so.

`CookieJar.set_cookie(cookie)`

Set a `Cookie`, without checking with policy to see whether or not it should be set.

`CookieJar.clear([domain[, path[, name ]]])`

Clear some cookies.

If invoked without arguments, clear all cookies. If given a single argument, only cookies belonging to that *domain* will be removed. If given two arguments, cookies belonging to the specified *domain* and URL *path* are removed. If given three arguments, then the cookie with the specified *domain*, *path* and *name* is removed.

Raises `KeyError` if no matching cookie exists.

`CookieJar.clear_session_cookies()`

Discard all session cookies.

Discards all contained cookies that have a true `discard` attribute (usually because they had either no `max-age` or `expires` cookie-attribute, or an explicit `discard` cookie-attribute). For interactive browsers, the end of a session usually corresponds to closing the browser window.

Note that the `save()` method won't save session cookies anyway, unless you ask otherwise by passing a true `ignore_discard` argument.

`FileCookieJar` implements the following additional methods:

`FileCookieJar.save(filename=None, ignore_discard=False, ignore_expires=False)`

Save cookies to a file.

This base class raises `NotImplementedError`. Subclasses may leave this method unimplemented.

*filename* is the name of file in which to save cookies. If *filename* is not specified, `self.filename` is used (whose default is the value passed to the constructor, if any); if `self.filename` is `None`, `ValueError` is raised.

*ignore\_discard*: save even cookies set to be discarded. *ignore\_expires*: save even cookies that have expired

The file is overwritten if it already exists, thus wiping all the cookies it contains. Saved cookies can be restored later using the `load()` or `revert()` methods.

`FileCookieJar.load(filename=None, ignore_discard=False, ignore_expires=False)`

Load cookies from a file.

Old cookies are kept unless overwritten by newly loaded ones.

Arguments are as for `save()`.

The named file must be in the format understood by the class, or `LoadError` will be raised. Also, `IOError` may be raised, for example if the file does not exist.

---

**Note:** For backwards-compatibility with Python 2.4 (which raised an `IOError`), `LoadError` is a subclass of `IOError`.

---

`FileCookieJar.revert(filename=None, ignore_discard=False, ignore_expires=False)`

Clear all cookies and reload cookies from a saved file.

`revert()` can raise the same exceptions as `load()`. If there is a failure, the object's state will not be altered.

`FileCookieJar` instances have the following public attributes:

`FileCookieJar.filename`

Filename of default file in which to keep cookies. This attribute may be assigned to.

`FileCookieJar.delayload`

If true, load cookies lazily from disk. This attribute should not be assigned to. This is only a hint, since this only affects performance, not behaviour (unless the cookies on disk are changing). A `CookieJar` object may ignore it. None of the `FileCookieJar` classes included in the standard library lazily loads cookies.

## 20.21.2 FileCookieJar subclasses and co-operation with web browsers

The following `CookieJar` subclasses are provided for reading and writing .

**class** `cookieilib.MozillaCookieJar` (*filename*, *delayload=None*, *policy=None*)

A `FileCookieJar` that can load from and save cookies to disk in the Mozilla `cookies.txt` file format (which is also used by the Lynx and Netscape browsers).

---

**Note:** Version 3 of the Firefox web browser no longer writes cookies in the `cookies.txt` file format.

---

**Note:** This loses information about RFC 2965 cookies, and also about newer or non-standard cookie-attributes such as `port`.

---

**Warning:** Back up your cookies before saving if you have cookies whose loss / corruption would be inconvenient (there are some subtleties which may lead to slight changes in the file over a load / save round-trip).

Also note that cookies saved while Mozilla is running will get clobbered by Mozilla.

**class** `cookieilib.LWPCookieJar` (*filename*, *delayload=None*, *policy=None*)

A `FileCookieJar` that can load from and save cookies to disk in format compatible with the libwww-perl library's `Set-Cookie3` file format. This is convenient if you want to store cookies in a human-readable file.

## 20.21.3 CookiePolicy Objects

Objects implementing the `CookiePolicy` interface have the following methods:

`CookiePolicy.set_ok` (*cookie*, *request*)

Return boolean value indicating whether cookie should be accepted from server.

*cookie* is a `cookieilib.Cookie` instance. *request* is an object implementing the interface defined by the documentation for `CookieJar.extract_cookies()`.

`CookiePolicy.return_ok` (*cookie*, *request*)

Return boolean value indicating whether cookie should be returned to server.

*cookie* is a `cookieilib.Cookie` instance. *request* is an object implementing the interface defined by the documentation for `CookieJar.add_cookie_header()`.

`CookiePolicy.domain_return_ok` (*domain*, *request*)

Return false if cookies should not be returned, given cookie domain.

This method is an optimization. It removes the need for checking every cookie with a particular domain (which might involve reading many files). Returning true from `domain_return_ok()` and `path_return_ok()` leaves all the work to `return_ok()`.

If `domain_return_ok()` returns true for the cookie domain, `path_return_ok()` is called for the cookie path. Otherwise, `path_return_ok()` and `return_ok()` are never called for that cookie domain. If

`path_return_ok()` returns true, `return_ok()` is called with the `Cookie` object itself for a full check. Otherwise, `return_ok()` is never called for that cookie path.

Note that `domain_return_ok()` is called for every *cookie* domain, not just for the *request* domain. For example, the function might be called with both `".example.com"` and `"www.example.com"` if the request domain is `"www.example.com"`. The same goes for `path_return_ok()`.

The *request* argument is as documented for `return_ok()`.

`CookiePolicy.path_return_ok(path, request)`

Return false if cookies should not be returned, given cookie path.

See the documentation for `domain_return_ok()`.

In addition to implementing the methods above, implementations of the `CookiePolicy` interface must also supply the following attributes, indicating which protocols should be used, and how. All of these attributes may be assigned to.

`CookiePolicy.netscape`

Implement Netscape protocol.

`CookiePolicy.rfc2965`

Implement RFC 2965 protocol.

`CookiePolicy.hide_cookie2`

Don't add `Cookie2` header to requests (the presence of this header indicates to the server that we understand RFC 2965 cookies).

The most useful way to define a `CookiePolicy` class is by subclassing from `DefaultCookiePolicy` and overriding some or all of the methods above. `CookiePolicy` itself may be used as a 'null policy' to allow setting and receiving any and all cookies (this is unlikely to be useful).

## 20.21.4 DefaultCookiePolicy Objects

Implements the standard rules for accepting and returning cookies.

Both RFC 2965 and Netscape cookies are covered. RFC 2965 handling is switched off by default.

The easiest way to provide your own policy is to override this class and call its methods in your overridden implementations before adding your own additional checks:

```
import cookielib
class MyCookiePolicy(cockielib.DefaultCookiePolicy):
    def set_ok(self, cookie, request):
        if not cookielib.DefaultCookiePolicy.set_ok(self, cookie, request):
            return False
        if i_dont_want_to_store_this_cookie(cookie):
            return False
        return True
```

In addition to the features required to implement the `CookiePolicy` interface, this class allows you to block and allow domains from setting and receiving cookies. There are also some strictness switches that allow you to tighten up the rather loose Netscape protocol rules a little bit (at the cost of blocking some benign cookies).

A domain blacklist and whitelist is provided (both off by default). Only domains not in the blacklist and present in the whitelist (if the whitelist is active) participate in cookie setting and returning. Use the `blocked_domains` constructor argument, and `blocked_domains()` and `set_blocked_domains()` methods (and the corresponding argument and methods for `allowed_domains`). If you set a whitelist, you can turn it off again by setting it to `None`.

Domains in block or allow lists that do not start with a dot must equal the cookie domain to be matched. For example, `"example.com"` matches a blacklist entry of `"example.com"`, but `"www.example.com"` does not. Domains

that do start with a dot are matched by more specific domains too. For example, both "www.example.com" and "www.coyote.example.com" match ".example.com" (but "example.com" itself does not). IP addresses are an exception, and must match exactly. For example, if `blocked_domains` contains "192.168.1.2" and ".168.1.2", 192.168.1.2 is blocked, but 193.168.1.2 is not.

`DefaultCookiePolicy` implements the following additional methods:

`DefaultCookiePolicy.blocked_domains()`

Return the sequence of blocked domains (as a tuple).

`DefaultCookiePolicy.set_blocked_domains(blocked_domains)`

Set the sequence of blocked domains.

`DefaultCookiePolicy.is_blocked(domain)`

Return whether *domain* is on the blacklist for setting or receiving cookies.

`DefaultCookiePolicy.allowed_domains()`

Return `None`, or the sequence of allowed domains (as a tuple).

`DefaultCookiePolicy.set_allowed_domains(allowed_domains)`

Set the sequence of allowed domains, or `None`.

`DefaultCookiePolicy.is_not_allowed(domain)`

Return whether *domain* is not on the whitelist for setting or receiving cookies.

`DefaultCookiePolicy` instances have the following attributes, which are all initialised from the constructor arguments of the same name, and which may all be assigned to.

`DefaultCookiePolicy.rfc2109_as_netscape`

If true, request that the `CookieJar` instance downgrade RFC 2109 cookies (ie. cookies received in a `Set-Cookie` header with a version cookie-attribute of 1) to Netscape cookies by setting the version attribute of the `Cookie` instance to 0. The default value is `None`, in which case RFC 2109 cookies are downgraded if and only if RFC 2965 handling is turned off. Therefore, RFC 2109 cookies are downgraded by default. New in version 2.5.

General strictness switches:

`DefaultCookiePolicy.strict_domain`

Don't allow sites to set two-component domains with country-code top-level domains like `.co.uk`, `.gov.uk`, `.co.nz`.etc. This is far from perfect and isn't guaranteed to work!

RFC 2965 protocol strictness switches:

`DefaultCookiePolicy.strict_rfc2965_unverifiable`

Follow RFC 2965 rules on unverifiable transactions (usually, an unverifiable transaction is one resulting from a redirect or a request for an image hosted on another site). If this is false, cookies are *never* blocked on the basis of verifiability

Netscape protocol strictness switches:

`DefaultCookiePolicy.strict_ns_unverifiable`

apply RFC 2965 rules on unverifiable transactions even to Netscape cookies

`DefaultCookiePolicy.strict_ns_domain`

Flags indicating how strict to be with domain-matching rules for Netscape cookies. See below for acceptable values.

`DefaultCookiePolicy.strict_ns_set_initial_dollar`

Ignore cookies in Set-Cookie: headers that have names starting with '\$'.

`DefaultCookiePolicy.strict_ns_set_path`

Don't allow setting cookies whose path doesn't path-match request URI.

`strict_ns_domain` is a collection of flags. Its value is constructed by or-ing together (for example, `DomainStrictNoDots|DomainStrictNonDomain` means both flags are set).

`DefaultCookiePolicy.DomainStrictNoDots`

When setting cookies, the ‘host prefix’ must not contain a dot (eg. `www.foo.bar.com` can’t set a cookie for `.bar.com`, because `www.foo` contains a dot).

`DefaultCookiePolicy.DomainStrictNonDomain`

Cookies that did not explicitly specify a domain cookie-attribute can only be returned to a domain equal to the domain that set the cookie (eg. `spam.example.com` won’t be returned cookies from `example.com` that had no domain cookie-attribute).

`DefaultCookiePolicy.DomainRFC2965Match`

When setting cookies, require a full RFC 2965 domain-match.

The following attributes are provided for convenience, and are the most useful combinations of the above flags:

`DefaultCookiePolicy.DomainLiberal`

Equivalent to 0 (ie. all of the above Netscape domain strictness flags switched off).

`DefaultCookiePolicy.DomainStrict`

Equivalent to `DomainStrictNoDots|DomainStrictNonDomain`.

## 20.21.5 Cookie Objects

`Cookie` instances have Python attributes roughly corresponding to the standard cookie-attributes specified in the various cookie standards. The correspondence is not one-to-one, because there are complicated rules for assigning default values, because the `max-age` and `expires` cookie-attributes contain equivalent information, and because RFC 2109 cookies may be ‘downgraded’ by `cookieilib` from version 1 to version 0 (Netscape) cookies.

Assignment to these attributes should not be necessary other than in rare circumstances in a `CookiePolicy` method. The class does not enforce internal consistency, so you should know what you’re doing if you do that.

`Cookie.version`

Integer or `None`. Netscape cookies have `version` 0. RFC 2965 and RFC 2109 cookies have a `version` cookie-attribute of 1. However, note that `cookieilib` may ‘downgrade’ RFC 2109 cookies to Netscape cookies, in which case `version` is 0.

`Cookie.name`

Cookie name (a string).

`Cookie.value`

Cookie value (a string), or `None`.

`Cookie.port`

String representing a port or a set of ports (eg. ‘80’, or ‘80,8080’), or `None`.

`Cookie.path`

Cookie path (a string, eg. ‘/acme/rocket\_launchers’).

`Cookie.secure`

True if cookie should only be returned over a secure connection.

`Cookie.expires`

Integer expiry date in seconds since epoch, or `None`. See also the `is_expired()` method.

`Cookie.discard`

True if this is a session cookie.

`Cookie.comment`

String comment from the server explaining the function of this cookie, or `None`.

### `Cookie.comment_url`

URL linking to a comment from the server explaining the function of this cookie, or `None`.

### `Cookie.rfc2109`

True if this cookie was received as an RFC 2109 cookie (ie. the cookie arrived in a `Set-Cookie` header, and the value of the Version cookie-attribute in that header was 1). This attribute is provided because `cookielib` may 'downgrade' RFC 2109 cookies to Netscape cookies, in which case `version` is 0. New in version 2.5.

### `Cookie.port_specified`

True if a port or set of ports was explicitly specified by the server (in the `Set-Cookie / Set-Cookie2` header).

### `Cookie.domain_specified`

True if a domain was explicitly specified by the server.

### `Cookie.domain_initial_dot`

True if the domain explicitly specified by the server began with a dot ('.').

Cookies may have additional non-standard cookie-attributes. These may be accessed using the following methods:

### `Cookie.has_nonstandard_attr(name)`

Return true if cookie has the named cookie-attribute.

### `Cookie.get_nonstandard_attr(name, default=None)`

If cookie has the named cookie-attribute, return its value. Otherwise, return `default`.

### `Cookie.set_nonstandard_attr(name, value)`

Set the value of the named cookie-attribute.

The `Cookie` class also defines the following method:

### `Cookie.is_expired([now=None])`

True if cookie has passed the time at which the server requested it should expire. If `now` is given (in seconds since the epoch), return whether the cookie has expired at the specified time.

## 20.21.6 Examples

The first example shows the most common usage of `cookielib`:

```
import cookielib, urllib2
cj = cookielib.CookieJar()
opener = urllib2.build_opener(urllib2.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

This example illustrates how to open a URL using your Netscape, Mozilla, or Lynx cookies (assumes Unix/Netscape convention for location of the cookies file):

```
import os, cookielib, urllib2
cj = cookielib.MozillaCookieJar()
cj.load(os.path.join(os.path.expanduser("~"), ".netscape", "cookies.txt"))
opener = urllib2.build_opener(urllib2.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

The next example illustrates the use of `DefaultCookiePolicy`. Turn on RFC 2965 cookies, be more strict about domains when setting and returning Netscape cookies, and block some domains from setting cookies or having them returned:

```
import urllib2
from cookielib import CookieJar, DefaultCookiePolicy
policy = DefaultCookiePolicy(
    rfc2965=True, strict_ns_domain=DefaultCookiePolicy.DomainStrict,
```

```
blocked_domains=["ads.net", ".ads.net"])
cj = CookieJar(policy)
opener = urllib2.build_opener(urllib2.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

## 20.22 Cookie — HTTP state management

**Note:** The `Cookie` module has been renamed to `http.cookies` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

**Source code:** `Lib/Cookie.py`

The `Cookie` module defines classes for abstracting the concept of cookies, an HTTP state management mechanism. It supports both simple string-only cookies, and provides an abstraction for having any serializable data-type as cookie value.

The module formerly strictly applied the parsing rules described in the

**RFC 2109** and **RFC 2068** specifications. It has since been discovered that MSIE 3.0x doesn't follow the character rules outlined in those specs and also many current day browsers and servers have relaxed parsing rules when comes to Cookie handling. As a result, the parsing rules used are a bit less strict.

The character set, `string.ascii_letters`, `string.digits` and `!#$%&'*+-.^_`|~` denote the set of valid characters allowed by this module in Cookie name (as `key`).

**Note:** On encountering an invalid cookie, `CookieError` is raised, so if your cookie data comes from a browser you should always prepare for invalid data and catch `CookieError` on parsing.

### exception `Cookie.CookieError`

Exception failing because of **RFC 2109** invalidity: incorrect attributes, incorrect `Set-Cookie` header, etc.

### class `Cookie.BaseCookie` (`[input]`)

This class is a dictionary-like object whose keys are strings and whose values are `Morsel` instances. Note that upon setting a key to a value, the value is first converted to a `Morsel` containing the key and the value.

If `input` is given, it is passed to the `load()` method.

### class `Cookie.SimpleCookie` (`[input]`)

This class derives from `BaseCookie` and overrides `value_decode()` and `value_encode()` to be the identity and `str()` respectively.

### class `Cookie.SerialCookie` (`[input]`)

This class derives from `BaseCookie` and overrides `value_decode()` and `value_encode()` to be the `pickle.loads()` and `pickle.dumps()`. **Deprecated since version 2.3:** Reading pickled values from untrusted cookie data is a huge security hole, as pickle strings can be crafted to cause arbitrary code to execute on your server. It is supported for backwards compatibility only, and may eventually go away.

### class `Cookie.SmartCookie` (`[input]`)

This class derives from `BaseCookie`. It overrides `value_decode()` to be `pickle.loads()` if it is a valid pickle, and otherwise the value itself. It overrides `value_encode()` to be `pickle.dumps()` unless it is a string, in which case it returns the value itself. **Deprecated since version 2.3:** The same security warning from `SerialCookie` applies here.

A further security note is warranted. For backwards compatibility, the `Cookie` module exports a class named `Cookie` which is just an alias for `SmartCookie`. This is probably a mistake and will likely be removed in a future version. You should not use the `Cookie` class in your applications, for the same reason why you should not use the `SerialCookie` class.

### See Also:

**Module `cookieclib`** HTTP cookie handling for web *clients*. The `cookieclib` and `Cookie` modules do not depend on each other.

**RFC 2109 - HTTP State Management Mechanism** This is the state management specification implemented by this module.

## 20.22.1 Cookie Objects

`BaseCookie.value_decode(val)`

Return a decoded value from a string representation. Return value can be any type. This method does nothing in `BaseCookie` — it exists so it can be overridden.

`BaseCookie.value_encode(val)`

Return an encoded value. *val* can be any type, but return value must be a string. This method does nothing in `BaseCookie` — it exists so it can be overridden

In general, it should be the case that `value_encode()` and `value_decode()` are inverses on the range of *value\_decode*.

`BaseCookie.output([attrs[, header[, sep]]])`

Return a string representation suitable to be sent as HTTP headers. *attrs* and *header* are sent to each `Morsel`'s `output()` method. *sep* is used to join the headers together, and is by default the combination `'\r\n'` (CRLF). Changed in version 2.5: The default separator has been changed from `'\n'` to match the cookie specification.

`BaseCookie.js_output([attrs])`

Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP headers was sent.

The meaning for *attrs* is the same as in `output()`.

`BaseCookie.load(rawdata)`

If *rawdata* is a string, parse it as an `HTTP_COOKIE` and add the values found there as `Morsels`. If it is a dictionary, it is equivalent to:

```
for k, v in rawdata.items():
    cookie[k] = v
```

## 20.22.2 Morsel Objects

**class `Cookie.Morsel`**

Abstract a key/value pair, which has some **RFC 2109** attributes.

`Morsels` are dictionary-like objects, whose set of keys is constant — the valid

**RFC 2109** attributes, which are

- `expires`
- `path`
- `comment`
- `domain`

- max-age
- secure
- version
- httponly

The attribute `httponly` specifies that the cookie is only transferred in HTTP requests, and is not accessible through JavaScript. This is intended to mitigate some forms of cross-site scripting.

The keys are case-insensitive. New in version 2.6: The `httponly` attribute was added.

**Morsel.value**

The value of the cookie.

**Morsel.coded\_value**

The encoded value of the cookie — this is what should be sent.

**Morsel.key**

The name of the cookie.

**Morsel.set** (*key*, *value*, *coded\_value*)

Set the *key*, *value* and *coded\_value* attributes.

**Morsel.isReservedKey** (*K*)

Whether *K* is a member of the set of keys of a `Morsel`.

**Morsel.output** ([*attrs*], [*header*])

Return a string representation of the `Morsel`, suitable to be sent as an HTTP header. By default, all the attributes are included, unless *attrs* is given, in which case it should be a list of attributes to use. *header* is by default "Set-Cookie:".

**Morsel.js\_output** ([*attrs*])

Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP header was sent.

The meaning for *attrs* is the same as in `output()`.

**Morsel.OutputString** ([*attrs*])

Return a string representing the `Morsel`, without any surrounding HTTP or JavaScript.

The meaning for *attrs* is the same as in `output()`.

### 20.22.3 Example

The following example demonstrates how to use the `Cookie` module.

```
>>> import Cookie
>>> C = Cookie.SimpleCookie()
>>> C["fig"] = "newton"
>>> C["sugar"] = "wafer"
>>> print C # generate HTTP headers
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> print C.output() # same thing
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> C = Cookie.SimpleCookie()
>>> C["rocky"] = "road"
>>> C["rocky"]["path"] = "/cookie"
```

```
>>> print C.output(header="Cookie:")
Cookie: rocky=road; Path=/cookie
>>> print C.output(attrs=[], header="Cookie:")
Cookie: rocky=road
>>> C = Cookie.SimpleCookie()
>>> C.load("chips=ahoy; vienna=finger") # load from a string (HTTP header)
>>> print C
Set-Cookie: chips=ahoy
Set-Cookie: vienna=finger
>>> C = Cookie.SimpleCookie()
>>> C.load('keebler="E=everybody; L=\\"Loves\\"; fudge=\012;';')
>>> print C
Set-Cookie: keebler="E=everybody; L=\\"Loves\\"; fudge=\012;"
>>> C = Cookie.SimpleCookie()
>>> C["oreo"] = "doublestuff"
>>> C["oreo"]["path"] = "/"
>>> print C
Set-Cookie: oreo=doublestuff; Path=/
>>> C["twix"] = "none for you"
>>> C["twix"].value
'none for you'
>>> C = Cookie.SimpleCookie()
>>> C["number"] = 7 # equivalent to C["number"] = str(7)
>>> C["string"] = "seven"
>>> C["number"].value
'7'
>>> C["string"].value
'seven'
>>> print C
Set-Cookie: number=7
Set-Cookie: string=seven
>>> # SerialCookie and SmartCookie are deprecated
>>> # using it can cause security loopholes in your code.
>>> C = Cookie.SerialCookie()
>>> C["number"] = 7
>>> C["string"] = "seven"
>>> C["number"].value
7
>>> C["string"].value
'seven'
>>> print C
Set-Cookie: number="I7\012."
Set-Cookie: string="S'seven'\012p1\012."
>>> C = Cookie.SmartCookie()
>>> C["number"] = 7
>>> C["string"] = "seven"
>>> C["number"].value
7
>>> C["string"].value
'seven'
>>> print C
Set-Cookie: number="I7\012."
Set-Cookie: string=seven
```

## 20.23 xmlrpclib — XML-RPC client access

**Note:** The `xmlrpclib` module has been renamed to `xmlrpc.client` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

New in version 2.2. **Source code:** [Lib/xmlrpclib.py](#)

XML-RPC is a Remote Procedure Call method that uses XML passed via HTTP as a transport. With it, a client can call methods with parameters on a remote server (the server is named by a URI) and get back structured data. This module supports writing XML-RPC client code; it handles all the details of translating between conformable Python objects and XML on the wire.

```
class xmlrpclib.ServerProxy (uri [, transport [, encoding [, verbose [, allow_none [, use_datetime ] ] ] ] ] )
```

A `ServerProxy` instance is an object that manages communication with a remote XML-RPC server. The required first argument is a URI (Uniform Resource Indicator), and will normally be the URL of the server. The optional second argument is a transport factory instance; by default it is an internal `SafeTransport` instance for https: URLs and an internal `HTTPTransport` instance otherwise. The optional third argument is an encoding, by default UTF-8. The optional fourth argument is a debugging flag. If `allow_none` is true, the Python constant `None` will be translated into XML; the default behaviour is for `None` to raise a `TypeError`. This is a commonly-used extension to the XML-RPC specification, but isn't supported by all clients and servers; see <http://ontosys.com/xml-rpc/extensions.php> for a description. The `use_datetime` flag can be used to cause date/time values to be presented as `datetime.datetime` objects; this is false by default. `datetime.datetime` objects may be passed to calls.

Both the HTTP and HTTPS transports support the URL syntax extension for HTTP Basic Authentication: `http://user:pass@host:port/path`. The `user:pass` portion will be base64-encoded as an HTTP 'Authorization' header, and sent to the remote server as part of the connection process when invoking an XML-RPC method. You only need to use this if the remote server requires a Basic Authentication user and password.

The returned instance is a proxy object with methods that can be used to invoke corresponding RPC calls on the remote server. If the remote server supports the introspection API, the proxy can also be used to query the remote server for the methods it supports (service discovery) and fetch other server-associated metadata.

`ServerProxy` instance methods take Python basic types and objects as arguments and return Python basic types and classes. Types that are conformable (e.g. that can be marshalled through XML), include the following (and except where noted, they are unmarshalled as the same Python type):

Name	Meaning
boolean	The <code>True</code> and <code>False</code> constants
integers	Pass in directly
floating-point numbers	Pass in directly
strings	Pass in directly
arrays	Any Python sequence type containing conformable elements. Arrays are returned as lists
structures	A Python dictionary. Keys must be strings, values may be any conformable type. Objects of user-defined classes can be passed in; only their <code>__dict__</code> attribute is transmitted.
dates	in seconds since the epoch (pass in an instance of the <code>DateTime</code> class) or a <code>datetime.datetime</code> instance.
binary data	pass in an instance of the <code>Binary</code> wrapper class

This is the full set of data types supported by XML-RPC. Method calls may also raise a special `Fault` instance, used to signal XML-RPC server errors, or `ProtocolError` used to signal an error in the HTTP/HTTPS

transport layer. Both `Fault` and `ProtocolError` derive from a base class called `Error`. Note that even though starting with Python 2.2 you can subclass built-in types, the `xmlrpclib` module currently does not marshal instances of such subclasses.

When passing strings, characters special to XML such as `<`, `>`, and `&` will be automatically escaped. However, it's the caller's responsibility to ensure that the string is free of characters that aren't allowed in XML, such as the control characters with ASCII values between 0 and 31 (except, of course, tab, newline and carriage return); failing to do this will result in an XML-RPC request that isn't well-formed XML. If you have to pass arbitrary strings via XML-RPC, use the `Binary` wrapper class described below.

`Server` is retained as an alias for `ServerProxy` for backwards compatibility. New code should use `ServerProxy`. Changed in version 2.5: The `use_datetime` flag was added. Changed in version 2.6: Instances of *new-style classes* can be passed in if they have an `__dict__` attribute and don't have a base class that is marshalled in a special way.

### See Also:

**XML-RPC HOWTO** A good description of XML-RPC operation and client software in several languages. Contains pretty much everything an XML-RPC client developer needs to know.

**XML-RPC Introspection** Describes the XML-RPC protocol extension for introspection.

**XML-RPC Specification** The official specification.

**Unofficial XML-RPC Errata** Fredrik Lundh's "unofficial errata, intended to clarify certain details in the XML-RPC specification, as well as hint at 'best practices' to use when designing your own XML-RPC implementations."

## 20.23.1 ServerProxy Objects

A `ServerProxy` instance has a method corresponding to each remote procedure call accepted by the XML-RPC server. Calling the method performs an RPC, dispatched by both name and argument signature (e.g. the same method name can be overloaded with multiple argument signatures). The RPC finishes by returning a value, which may be either returned data in a conformant type or a `Fault` or `ProtocolError` object indicating an error.

Servers that support the XML introspection API support some common methods grouped under the reserved `system` attribute:

`ServerProxy.system.listMethods()`

This method returns a list of strings, one for each (non-system) method supported by the XML-RPC server.

`ServerProxy.system.methodSignature(name)`

This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns an array of possible signatures for this method. A signature is an array of types. The first of these types is the return type of the method, the rest are parameters.

Because multiple signatures (ie. overloading) is permitted, this method returns a list of signatures rather than a singleton.

Signatures themselves are restricted to the top level parameters expected by a method. For instance if a method expects one array of structs as a parameter, and it returns a string, its signature is simply "string, array". If it expects three integers and returns a string, its signature is "string, int, int, int".

If no signature is defined for the method, a non-array value is returned. In Python this means that the type of the returned value will be something other than list.

`ServerProxy.system.methodHelp(name)`

This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns a documentation string describing the use of that method. If no such string is available, an empty string is returned. The documentation string may contain HTML markup.

## 20.23.2 Boolean Objects

This class may be initialized from any Python value; the instance returned depends only on its truth value. It supports various Python operators through `__cmp__()`, `__repr__()`, `__int__()`, and `__nonzero__()` methods, all implemented in the obvious ways.

It also has the following method, supported mainly for internal use by the unmarshalling code:

`Boolean.encode(out)`

Write the XML-RPC encoding of this Boolean item to the out stream object.

A working example follows. The server code:

```
import xmlrpclib
from SimpleXMLRPCServer import SimpleXMLRPCServer

def is_even(n):
    return n%2 == 0

server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000..."
server.register_function(is_even, "is_even")
server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy("http://localhost:8000/")
print "3 is even: %s" % str(proxy.is_even(3))
print "100 is even: %s" % str(proxy.is_even(100))
```

## 20.23.3 DateTime Objects

This class may be initialized with seconds since the epoch, a time tuple, an ISO 8601 time/date string, or a `datetime.datetime` instance. It has the following methods, supported mainly for internal use by the marshalling/unmarshalling code:

`DateTime.decode(string)`

Accept a string as the instance's new time value.

`DateTime.encode(out)`

Write the XML-RPC encoding of this DateTime item to the *out* stream object.

It also supports certain of Python's built-in operators through `__cmp__()` and `__repr__()` methods.

A working example follows. The server code:

```
import datetime
from SimpleXMLRPCServer import SimpleXMLRPCServer
import xmlrpclib

def today():
    today = datetime.datetime.today()
    return xmlrpclib.DateTime(today)

server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000..."
```

```
server.register_function(today, "today")
server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpclib
import datetime

proxy = xmlrpclib.ServerProxy("http://localhost:8000/")

today = proxy.today()
# convert the ISO8601 string to a datetime object
converted = datetime.datetime.strptime(today.value, "%Y%m%dT%H:%M:%S")
print "Today: %s" % converted.strftime("%d.%m.%Y, %H:%M")
```

### 20.23.4 Binary Objects

This class may be initialized from string data (which may include NULs). The primary access to the content of a Binary object is provided by an attribute:

Binary.**data**

The binary data encapsulated by the Binary instance. The data is provided as an 8-bit string.

Binary objects have the following methods, supported mainly for internal use by the marshalling/unmarshalling code:

Binary.**decode** (*string*)

Accept a base64 string and decode it as the instance's new data.

Binary.**encode** (*out*)

Write the XML-RPC base 64 encoding of this binary item to the out stream object.

The encoded data will have newlines every 76 characters as per RFC 2045 section 6.8, which was the de facto standard base64 specification when the XML-RPC spec was written.

It also supports certain of Python's built-in operators through a `__cmp__()` method.

Example usage of the binary objects. We're going to transfer an image over XMLRPC:

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import xmlrpclib

def python_logo():
    with open("python_logo.jpg", "rb") as handle:
        return xmlrpclib.Binary(handle.read())

server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000..."
server.register_function(python_logo, 'python_logo')

server.serve_forever()
```

The client gets the image and saves it to a file:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy("http://localhost:8000/")
with open("fetched_python_logo.jpg", "wb") as handle:
    handle.write(proxy.python_logo().data)
```

## 20.23.5 Fault Objects

A `Fault` object encapsulates the content of an XML-RPC fault tag. Fault objects have the following attributes:

`Fault.faultCode`

A string indicating the fault type.

`Fault.faultString`

A string containing a diagnostic message associated with the fault.

In the following example we're going to intentionally cause a `Fault` by returning a complex type object. The server code:

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

# A marshalling error is going to occur because we're returning a
# complex number
def add(x,y):
    return x+y+0j

server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000..."
server.register_function(add, 'add')

server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy("http://localhost:8000/")
try:
    proxy.add(2, 5)
except xmlrpclib.Fault, err:
    print "A fault occurred"
    print "Fault code: %d" % err.faultCode
    print "Fault string: %s" % err.faultString
```

## 20.23.6 ProtocolError Objects

A `ProtocolError` object describes a protocol error in the underlying transport layer (such as a 404 'not found' error if the server named by the URI does not exist). It has the following attributes:

`ProtocolError.url`

The URI or URL that triggered the error.

`ProtocolError.errcode`

The error code.

`ProtocolError.errmsg`

The error message or diagnostic string.

`ProtocolError.headers`

A string containing the headers of the HTTP/HTTPS request that triggered the error.

In the following example we're going to intentionally cause a `ProtocolError` by providing an URI that doesn't point to an XMLRPC server:

```
import xmlrpclib

# create a ServerProxy with an URI that doesn't respond to XMLRPC requests
proxy = xmlrpclib.ServerProxy("http://www.google.com/")

try:
    proxy.some_method()
except xmlrpclib.ProtocolError, err:
    print "A protocol error occurred"
    print "URL: %s" % err.url
    print "HTTP/HTTPS headers: %s" % err.headers
    print "Error code: %d" % err.errcode
    print "Error message: %s" % err.errmsg
```

## 20.23.7 MultiCall Objects

New in version 2.4. The `MultiCall` object provides a way to encapsulate multiple calls to a remote server into a single request<sup>3</sup>.

**class** `xmlrpclib.MultiCall` (*server*)

Create an object used to boxcar method calls. *server* is the eventual target of the call. Calls can be made to the result object, but they will immediately return `None`, and only store the call name and parameters in the `MultiCall` object. Calling the object itself causes all stored calls to be transmitted as a single `system.multicall` request. The result of this call is a *generator*; iterating over this generator yields the individual results.

A usage example of this class follows. The server code

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

def add(x, y):
    return x+y

def subtract(x, y):
    return x-y

def multiply(x, y):
    return x*y

def divide(x, y):
    return x/y

# A simple server with simple arithmetic functions
server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000..."
server.register_multicall_functions()
server.register_function(add, 'add')
server.register_function(subtract, 'subtract')
server.register_function(multiply, 'multiply')
server.register_function(divide, 'divide')
server.serve_forever()
```

The client code for the preceding server:

---

<sup>3</sup> This approach has been first presented in a discussion on [xmlrpc.com](http://xmlrpc.com).

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy("http://localhost:8000/")
multicall = xmlrpclib.MultiCall(proxy)
multicall.add(7, 3)
multicall.subtract(7, 3)
multicall.multiply(7, 3)
multicall.divide(7, 3)
result = multicall()

print "7+3=%d, 7-3=%d, 7*3=%d, 7/3=%d" % tuple(result)
```

## 20.23.8 Convenience Functions

`xmlrpclib.boolean` (*value*)

Convert any Python value to one of the XML-RPC Boolean constants, True or False.

`xmlrpclib.dumps` (*params*[, *methodname*[, *methodresponse*[, *encoding*[, *allow\_none* ]]]])

Convert *params* into an XML-RPC request. or into a response if *methodresponse* is true. *params* can be either a tuple of arguments or an instance of the Fault exception class. If *methodresponse* is true, only a single value can be returned, meaning that *params* must be of length 1. *encoding*, if supplied, is the encoding to use in the generated XML; the default is UTF-8. Python's None value cannot be used in standard XML-RPC; to allow using it via an extension, provide a true value for *allow\_none*.

`xmlrpclib.loads` (*data*[, *use\_datetime* ])

Convert an XML-RPC request or response into Python objects, a (*params*, *methodname*). *params* is a tuple of argument; *methodname* is a string, or None if no method name is present in the packet. If the XML-RPC packet represents a fault condition, this function will raise a Fault exception. The *use\_datetime* flag can be used to cause date/time values to be presented as `datetime.datetime` objects; this is false by default. Changed in version 2.5: The *use\_datetime* flag was added.

## 20.23.9 Example of Client Usage

```
# simple test program (from the XML-RPC specification)
from xmlrpclib import ServerProxy, Error

# server = ServerProxy("http://localhost:8000") # local server
server = ServerProxy("http://betty.userland.com")

print server

try:
    print server.examples.getStateName(41)
except Error, v:
    print "ERROR", v
```

To access an XML-RPC server through a proxy, you need to define a custom transport. The following example shows how:

```
import xmlrpclib, httplib

class ProxiedTransport(xmlrpclib.Transport):
    def set_proxy(self, proxy):
        self.proxy = proxy
```

```
def make_connection(self, host):
    self.realhost = host
    h = httplib.HTTP(self.proxy)
    return h
def send_request(self, connection, handler, request_body):
    connection.putrequest("POST", 'http://%s%s' % (self.realhost, handler))
def send_host(self, connection, host):
    connection.putheader('Host', self.realhost)
```

```
p = ProxiedTransport()
p.set_proxy('proxy-server:8080')
server = xmlrpclib.Server('http://time.xmlrpc.com/RPC2', transport=p)
print server.currentTime.getCurrentTime()
```

### 20.23.10 Example of Client and Server Usage

See *SimpleXMLRPCServer Example*.

## 20.24 SimpleXMLRPCServer — Basic XML-RPC server

---

**Note:** The `SimpleXMLRPCServer` module has been merged into `xmlrpc.server` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

New in version 2.2. **Source code:** [Lib/SimpleXMLRPCServer.py](#)

---

The `SimpleXMLRPCServer` module provides a basic server framework for XML-RPC servers written in Python. Servers can either be free standing, using `SimpleXMLRPCServer`, or embedded in a CGI environment, using `CGIXMLRPCRequestHandler`.

**class** `SimpleXMLRPCServer.SimpleXMLRPCServer`(*addr*[, *requestHandler*[, *logRequests*[, *allow\_none*[, *encoding*[, *bind\_and\_activate*]]]])

Create a new server instance. This class provides methods for registration of functions that can be called by the XML-RPC protocol. The *requestHandler* parameter should be a factory for request handler instances; it defaults to `SimpleXMLRPCRequestHandler`. The *addr* and *requestHandler* parameters are passed to the `SocketServer.TCPServer` constructor. If *logRequests* is true (the default), requests will be logged; setting this parameter to false will turn off logging. The *allow\_none* and *encoding* parameters are passed on to `xmlrpclib` and control the XML-RPC responses that will be returned from the server. The *bind\_and\_activate* parameter controls whether `server_bind()` and `server_activate()` are called immediately by the constructor; it defaults to true. Setting it to false allows code to manipulate the *allow\_reuse\_address* class variable before the address is bound. Changed in version 2.5: The *allow\_none* and *encoding* parameters were added. Changed in version 2.6: The *bind\_and\_activate* parameter was added.

**class** `SimpleXMLRPCServer.CGIXMLRPCRequestHandler`(*allow\_none*[, *encoding*])

Create a new instance to handle XML-RPC requests in a CGI environment. The *allow\_none* and *encoding* parameters are passed on to `xmlrpclib` and control the XML-RPC responses that will be returned from the server. New in version 2.3. Changed in version 2.5: The *allow\_none* and *encoding* parameters were added.

**class** `SimpleXMLRPCServer.SimpleXMLRPCRequestHandler`

Create a new request handler instance. This request handler supports POST requests and modifies logging so that the *logRequests* parameter to the `SimpleXMLRPCServer` constructor parameter is honored.

## 20.24.1 SimpleXMLRPCServer Objects

The `SimpleXMLRPCServer` class is based on `SocketServer.TCPServer` and provides a means of creating simple, stand alone XML-RPC servers.

`SimpleXMLRPCServer.register_function` (*function* [, *name* ])

Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with *function*, otherwise *function.\_\_name\_\_* will be used. *name* can be either a normal or Unicode string, and may contain characters not legal in Python identifiers, including the period character.

`SimpleXMLRPCServer.register_instance` (*instance* [, *allow\_dotted\_names* ])

Register an object which is used to expose method names which have not been registered using `register_function()`. If *instance* contains a `_dispatch()` method, it is called with the requested method name and the parameters from the request. Its API is `def _dispatch(self, method, params)` (note that *params* does not represent a variable argument list). If it calls an underlying function to perform its task, that function is called as `func(*params)`, expanding the parameter list. The return value from `_dispatch()` is returned to the client as the result. If *instance* does not have a `_dispatch()` method, it is searched for an attribute matching the name of the requested method.

If the optional *allow\_dotted\_names* argument is true and the instance does not have a `_dispatch()` method, then if the requested method name contains periods, each component of the method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

**Warning:** Enabling the *allow\_dotted\_names* option allows intruders to access your module's global variables and may allow intruders to execute arbitrary code on your machine. Only use this option on a secure, closed network.

Changed in version 2.3.5: 2.4.1 *allow\_dotted\_names* was added to plug a security hole; prior versions are insecure.

`SimpleXMLRPCServer.register_introspection_functions` ()

Registers the XML-RPC introspection functions `system.listMethods`, `system.methodHelp` and `system.methodSignature`. New in version 2.3.

`SimpleXMLRPCServer.register_multicall_functions` ()

Registers the XML-RPC multicall function `system.multicall`.

`SimpleXMLRPCRequestHandler.rpc_paths`

An attribute value that must be a tuple listing valid path portions of the URL for receiving XML-RPC requests. Requests posted to other paths will result in a 404 “no such page” HTTP error. If this tuple is empty, all paths will be considered valid. The default value is `( '/', '/RPC2' )`. New in version 2.5.

`SimpleXMLRPCRequestHandler.encode_threshold`

If this attribute is not `None`, responses larger than this value will be encoded using the *gzip* transfer encoding, if permitted by the client. The default is 1400 which corresponds roughly to a single TCP packet. New in version 2.7.

### SimpleXMLRPCServer Example

Server code:

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
from SimpleXMLRPCServer import SimpleXMLRPCRequestHandler

# Restrict to a particular path.
class RequestHandler(SimpleXMLRPCRequestHandler):
    rpc_paths = ('/RPC2',)
```

```
# Create server
server = SimpleXMLRPCServer(("localhost", 8000),
                             requestHandler=RequestHandler)
server.register_introspection_functions()

# Register pow() function; this will use the value of
# pow.__name__ as the name, which is just 'pow'.
server.register_function(pow)

# Register a function under a different name
def adder_function(x,y):
    return x + y
server.register_function(adder_function, 'add')

# Register an instance; all the methods of the instance are
# published as XML-RPC methods (in this case, just 'div').
class MyFuncs:
    def div(self, x, y):
        return x // y

server.register_instance(MyFuncs())

# Run the server's main loop
server.serve_forever()
```

The following client code will call the methods made available by the preceding server:

```
import xmlrpclib

s = xmlrpclib.ServerProxy('http://localhost:8000')
print s.pow(2,3) # Returns 2**3 = 8
print s.add(2,3) # Returns 5
print s.div(5,2) # Returns 5//2 = 2

# Print list of available methods
print s.system.listMethods()
```

## 20.24.2 CGIXMLRPCRequestHandler

The `CGIXMLRPCRequestHandler` class can be used to handle XML-RPC requests sent to Python CGI scripts.

`CGIXMLRPCRequestHandler.register_function(function[, name])`

Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with *function*, otherwise *function.\_\_name\_\_* will be used. *name* can be either a normal or Unicode string, and may contain characters not legal in Python identifiers, including the period character.

`CGIXMLRPCRequestHandler.register_instance(instance)`

Register an object which is used to expose method names which have not been registered using `register_function()`. If *instance* contains a `_dispatch()` method, it is called with the requested method name and the parameters from the request; the return value is returned to the client as the result. If *instance* does not have a `_dispatch()` method, it is searched for an attribute matching the name of the requested method; if the requested method name contains periods, each component of the method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

`CGIXMLRPCRequestHandler.register_introspection_functions()`  
 Register the XML-RPC introspection functions `system.listMethods`, `system.methodHelp` and `system.methodSignature`.

`CGIXMLRPCRequestHandler.register_multicall_functions()`  
 Register the XML-RPC multicall function `system.multicall`.

`CGIXMLRPCRequestHandler.handle_request([request_text = None])`  
 Handle a XML-RPC request. If `request_text` is given, it should be the POST data provided by the HTTP server, otherwise the contents of stdin will be used.

Example:

```
class MyFuncs:
    def div(self, x, y) : return x // y
```

```
handler = CGIXMLRPCRequestHandler()
handler.register_function(pow)
handler.register_function(lambda x,y: x+y, 'add')
handler.register_introspection_functions()
handler.register_instance(MyFuncs())
handler.handle_request()
```

## 20.25 DocXMLRPCServer — Self-documenting XML-RPC server

**Note:** The `DocXMLRPCServer` module has been merged into `xmlrpc.server` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

New in version 2.3. The `DocXMLRPCServer` module extends the classes found in `SimpleXMLRPCServer` to serve HTML documentation in response to HTTP GET requests. Servers can either be free standing, using `DocXMLRPCServer`, or embedded in a CGI environment, using `DocCGIXMLRPCRequestHandler`.

**class** `DocXMLRPCServer.DocXMLRPCServer`(`addr`[, `requestHandler`[, `logRequests`[, `allow_none`[, `encoding`[, `bind_and_activate`]]]]])  
 Create a new server instance. All parameters have the same meaning as for `SimpleXMLRPCServer.SimpleXMLRPCServer`; `requestHandler` defaults to `DocXMLRPCRequestHandler`.

**class** `DocXMLRPCServer.DocCGIXMLRPCRequestHandler`  
 Create a new instance to handle XML-RPC requests in a CGI environment.

**class** `DocXMLRPCServer.DocXMLRPCRequestHandler`  
 Create a new request handler instance. This request handler supports XML-RPC POST requests, documentation GET requests, and modifies logging so that the `logRequests` parameter to the `DocXMLRPCServer` constructor parameter is honored.

### 20.25.1 DocXMLRPCServer Objects

The `DocXMLRPCServer` class is derived from `SimpleXMLRPCServer.SimpleXMLRPCServer` and provides a means of creating self-documenting, stand alone XML-RPC servers. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

`DocXMLRPCServer.set_server_title` (*server\_title*)

Set the title used in the generated HTML documentation. This title will be used inside the HTML “title” element.

`DocXMLRPCServer.set_server_name` (*server\_name*)

Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a “h1” element.

`DocXMLRPCServer.set_server_documentation` (*server\_documentation*)

Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.

### 20.25.2 DocCGIXMLRPCRequestHandler

The `DocCGIXMLRPCRequestHandler` class is derived from `SimpleXMLRPCServer.CGIXMLRPCRequestHandler` and provides a means of creating self-documenting, XML-RPC CGI scripts. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

`DocCGIXMLRPCRequestHandler.set_server_title` (*server\_title*)

Set the title used in the generated HTML documentation. This title will be used inside the HTML “title” element.

`DocCGIXMLRPCRequestHandler.set_server_name` (*server\_name*)

Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a “h1” element.

`DocCGIXMLRPCRequestHandler.set_server_documentation` (*server\_documentation*)

Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.

# MULTIMEDIA SERVICES

The modules described in this chapter implement various algorithms or interfaces that are mainly useful for multimedia applications. They are available at the discretion of the installation. Here's an overview:

## 21.1 `audioop` — Manipulate raw audio data

The `audioop` module contains some useful operations on sound fragments. It operates on sound fragments consisting of signed integer samples 8, 16 or 32 bits wide, stored in Python strings. This is the same format as used by the `al` and `sunaudiodev` modules. All scalar items are integers, unless specified otherwise.

This module provides support for a-LAW, u-LAW and Intel/DVI ADPCM encodings.

A few of the more complicated operations only take 16-bit samples, otherwise the sample size (in bytes) is always a parameter of the operation.

The module defines the following variables and functions:

**exception** `audioop.error`

This exception is raised on all errors, such as unknown number of bytes per sample, etc.

`audioop.add` (*fragment1*, *fragment2*, *width*)

Return a fragment which is the addition of the two samples passed as parameters. *width* is the sample width in bytes, either 1, 2 or 4. Both fragments should have the same length.

`audioop.adpcm2lin` (*adpcmfragment*, *width*, *state*)

Decode an Intel/DVI ADPCM coded fragment to a linear fragment. See the description of `lin2adpcm()` for details on ADPCM coding. Return a tuple (*sample*, *newstate*) where the sample has the width specified in *width*.

`audioop.alaw2lin` (*fragment*, *width*)

Convert sound fragments in a-LAW encoding to linearly encoded sound fragments. a-LAW encoding always uses 8 bits samples, so *width* refers only to the sample width of the output fragment here. New in version 2.5.

`audioop.avg` (*fragment*, *width*)

Return the average over all samples in the fragment.

`audioop.avgpp` (*fragment*, *width*)

Return the average peak-peak value over all samples in the fragment. No filtering is done, so the usefulness of this routine is questionable.

`audioop.bias` (*fragment*, *width*, *bias*)

Return a fragment that is the original fragment with a bias added to each sample.

`audioop.cross` (*fragment*, *width*)

Return the number of zero crossings in the fragment passed as an argument.

`audioop.findfactor` (*fragment, reference*)

Return a factor  $F$  such that `rms(add(fragment, mul(reference, -F)))` is minimal, i.e., return the factor with which you should multiply *reference* to make it match as well as possible to *fragment*. The fragments should both contain 2-byte samples.

The time taken by this routine is proportional to `len(fragment)`.

`audioop.findfit` (*fragment, reference*)

Try to match *reference* as well as possible to a portion of *fragment* (which should be the longer fragment). This is (conceptually) done by taking slices out of *fragment*, using `findfactor()` to compute the best match, and minimizing the result. The fragments should both contain 2-byte samples. Return a tuple (*offset, factor*) where *offset* is the (integer) offset into *fragment* where the optimal match started and *factor* is the (floating-point) factor as per `findfactor()`.

`audioop.findmax` (*fragment, length*)

Search *fragment* for a slice of length *length* samples (not bytes!) with maximum energy, i.e., return *i* for which `rms(fragment[i*2:(i+length)*2])` is maximal. The fragments should both contain 2-byte samples.

The routine takes time proportional to `len(fragment)`.

`audioop.getsample` (*fragment, width, index*)

Return the value of sample *index* from the fragment.

`audioop.lin2adpcm` (*fragment, width, state*)

Convert samples to 4 bit Intel/DVI ADPCM encoding. ADPCM coding is an adaptive coding scheme, whereby each 4 bit number is the difference between one sample and the next, divided by a (varying) step. The Intel/DVI ADPCM algorithm has been selected for use by the IMA, so it may well become a standard.

*state* is a tuple containing the state of the coder. The coder returns a tuple (*adpcmfrag, newstate*), and the *newstate* should be passed to the next call of `lin2adpcm()`. In the initial call, `None` can be passed as the state. *adpcmfrag* is the ADPCM coded fragment packed 2 4-bit values per byte.

`audioop.lin2alaw` (*fragment, width*)

Convert samples in the audio fragment to a-LAW encoding and return this as a Python string. a-LAW is an audio encoding format whereby you get a dynamic range of about 13 bits using only 8 bit samples. It is used by the Sun audio hardware, among others. New in version 2.5.

`audioop.lin2lin` (*fragment, width, newwidth*)

Convert samples between 1-, 2- and 4-byte formats.

---

**Note:** In some audio formats, such as .WAV files, 16 and 32 bit samples are signed, but 8 bit samples are unsigned. So when converting to 8 bit wide samples for these formats, you need to also add 128 to the result:

```
new_frames = audioop.lin2lin(frames, old_width, 1)
new_frames = audioop.bias(new_frames, 1, 128)
```

The same, in reverse, has to be applied when converting from 8 to 16 or 32 bit width samples.

---

`audioop.lin2ulaw` (*fragment, width*)

Convert samples in the audio fragment to u-LAW encoding and return this as a Python string. u-LAW is an audio encoding format whereby you get a dynamic range of about 14 bits using only 8 bit samples. It is used by the Sun audio hardware, among others.

`audioop.minmax` (*fragment, width*)

Return a tuple consisting of the minimum and maximum values of all samples in the sound fragment.

`audioop.max` (*fragment, width*)

Return the maximum of the *absolute value* of all samples in a fragment.

`audioop.maxpp` (*fragment, width*)

Return the maximum peak-peak value in the sound fragment.

`audioop.mul` (*fragment, width, factor*)

Return a fragment that has all samples in the original fragment multiplied by the floating-point value *factor*. Overflow is silently ignored.

`audioop.ratecv` (*fragment, width, nchannels, inrate, outrate, state* [, *weightA* [, *weightB* ]])

Convert the frame rate of the input fragment.

*state* is a tuple containing the state of the converter. The converter returns a tuple (*newfragment, newstate*), and *newstate* should be passed to the next call of `ratecv()`. The initial call should pass `None` as the state.

The *weightA* and *weightB* arguments are parameters for a simple digital filter and default to 1 and 0 respectively.

`audioop.reverse` (*fragment, width*)

Reverse the samples in a fragment and returns the modified fragment.

`audioop.rms` (*fragment, width*)

Return the root-mean-square of the fragment, i.e.  $\sqrt{\text{sum}(S_i^2)/n}$ .

This is a measure of the power in an audio signal.

`audioop.tomono` (*fragment, width, lfactor, rfactor*)

Convert a stereo fragment to a mono fragment. The left channel is multiplied by *lfactor* and the right channel by *rfactor* before adding the two channels to give a mono signal.

`audioop.tostereo` (*fragment, width, lfactor, rfactor*)

Generate a stereo fragment from a mono fragment. Each pair of samples in the stereo fragment are computed from the mono sample, whereby left channel samples are multiplied by *lfactor* and right channel samples by *rfactor*.

`audioop.ulaw2lin` (*fragment, width*)

Convert sound fragments in u-LAW encoding to linearly encoded sound fragments. u-LAW encoding always uses 8 bits samples, so *width* refers only to the sample width of the output fragment here.

Note that operations such as `mul()` or `max()` make no distinction between mono and stereo fragments, i.e. all samples are treated equal. If this is a problem the stereo fragment should be split into two mono fragments first and recombined later. Here is an example of how to do that:

```
def mul_stereo(sample, width, lfactor, rfactor):
    lsample = audioop.tomono(sample, width, 1, 0)
    rsample = audioop.tomono(sample, width, 0, 1)
    lsample = audioop.mul(lsample, width, lfactor)
    rsample = audioop.mul(rsample, width, rfactor)
    lsample = audioop.tostereo(lsample, width, 1, 0)
    rsample = audioop.tostereo(rsample, width, 0, 1)
    return audioop.add(lsample, rsample, width)
```

If you use the ADPCM coder to build network packets and you want your protocol to be stateless (i.e. to be able to tolerate packet loss) you should not only transmit the data but also the state. Note that you should send the *initial* state (the one you passed to `lin2adpcm()`) along to the decoder, not the final state (as returned by the coder). If you want to use `struct.struct()` to store the state in binary you can code the first element (the predicted value) in 16 bits and the second (the delta index) in 8.

The ADPCM coders have never been tried against other ADPCM coders, only against themselves. It could well be that I misinterpreted the standards in which case they will not be interoperable with the respective standards.

The `find*()` routines might look a bit funny at first sight. They are primarily meant to do echo cancellation. A reasonably fast way to do this is to pick the most energetic piece of the output sample, locate that in the input sample

and subtract the whole output sample from the input sample:

```
def echocancel(outputdata, inputdata):
    pos = audioop.findmax(outputdata, 800)      # one tenth second
    out_test = outputdata[pos*2:]
    in_test = inputdata[pos*2:]
    ipos, factor = audioop.findfit(in_test, out_test)
    # Optional (for better cancellation):
    # factor = audioop.findfactor(in_test[ipos*2:ipos*2+len(out_test)],
    #                             out_test)
    prefill = '\0' * (pos+ipos)*2
    postfill = '\0' * (len(inputdata)-len(prefill)-len(outputdata))
    outputdata = prefill + audioop.mul(outputdata,2,-factor) + postfill
    return audioop.add(inputdata, outputdata, 2)
```

## 21.2 imageop — Manipulate raw image data

Deprecated since version 2.6: The `imageop` module has been removed in Python 3. The `imageop` module contains some useful operations on images. It operates on images consisting of 8 or 32 bit pixels stored in Python strings. This is the same format as used by `gl.rectwrite()` and the `imgfile` module.

The module defines the following variables and functions:

### exception `imageop.error`

This exception is raised on all errors, such as unknown number of bits per pixel, etc.

`imageop.crop` (*image, psize, width, height, x0, y0, x1, y1*)

Return the selected part of *image*, which should be *width* by *height* in size and consist of pixels of *psize* bytes. *x0, y0, x1* and *y1* are like the `gl.rectread()` parameters, i.e. the boundary is included in the new image. The new boundaries need not be inside the picture. Pixels that fall outside the old image will have their value set to zero. If *x0* is bigger than *x1* the new image is mirrored. The same holds for the *y* coordinates.

`imageop.scale` (*image, psize, width, height, newwidth, newheight*)

Return *image* scaled to size *newwidth* by *newheight*. No interpolation is done, scaling is done by simple-minded pixel duplication or removal. Therefore, computer-generated images or dithered images will not look nice after scaling.

`imageop.tovideo` (*image, psize, width, height*)

Run a vertical low-pass filter over an image. It does so by computing each destination pixel as the average of two vertically-aligned source pixels. The main use of this routine is to forestall excessive flicker if the image is displayed on a video device that uses interlacing, hence the name.

`imageop.grey2mono` (*image, width, height, threshold*)

Convert a 8-bit deep greyscale image to a 1-bit deep image by thresholding all the pixels. The resulting image is tightly packed and is probably only useful as an argument to `mono2grey()`.

`imageop.dither2mono` (*image, width, height*)

Convert an 8-bit greyscale image to a 1-bit monochrome image using a (simple-minded) dithering algorithm.

`imageop.mono2grey` (*image, width, height, p0, p1*)

Convert a 1-bit monochrome image to an 8 bit greyscale or color image. All pixels that are zero-valued on input get value *p0* on output and all one-value input pixels get value *p1* on output. To convert a monochrome black-and-white image to greyscale pass the values 0 and 255 respectively.

`imageop.grey2grey4` (*image, width, height*)

Convert an 8-bit greyscale image to a 4-bit greyscale image without dithering.

`imageop.greyscale2grey2` (*image*, *width*, *height*)

Convert an 8-bit greyscale image to a 2-bit greyscale image without dithering.

`imageop.dither2grey2` (*image*, *width*, *height*)

Convert an 8-bit greyscale image to a 2-bit greyscale image with dithering. As for `dither2mono()`, the dithering algorithm is currently very simple.

`imageop.greyscale42grey` (*image*, *width*, *height*)

Convert a 4-bit greyscale image to an 8-bit greyscale image.

`imageop.greyscale22grey` (*image*, *width*, *height*)

Convert a 2-bit greyscale image to an 8-bit greyscale image.

`imageop.backward_compatible`

If set to 0, the functions in this module use a non-backward compatible way of representing multi-byte pixels on little-endian systems. The SGI for which this module was originally written is a big-endian system, so setting this variable will have no effect. However, the code wasn't originally intended to run on anything else, so it made assumptions about byte order which are not universal. Setting this variable to 0 will cause the byte order to be reversed on little-endian systems, so that it then is the same as on big-endian systems.

## 21.3 aifc — Read and write AIFF and AIFC files

**Source code:** `Lib/aifc.py`

This module provides support for reading and writing AIFF and AIFF-C files. AIFF is Audio Interchange File Format, a format for storing digital audio samples in a file. AIFF-C is a newer version of the format that includes the ability to compress the audio data.

**Note:** Some operations may only work under IRIX; these will raise `ImportError` when attempting to import the `c1` module, which is only available on IRIX.

Audio files have a number of parameters that describe the audio data. The sampling rate or frame rate is the number of times per second the sound is sampled. The number of channels indicate if the audio is mono, stereo, or quadro. Each frame consists of one sample per channel. The sample size is the size in bytes of each sample. Thus a frame consists of  $nchannels * samplesize$  bytes, and a second's worth of audio consists of  $nchannels * samplesize * framerate$  bytes.

For example, CD quality audio has a sample size of two bytes (16 bits), uses two channels (stereo) and has a frame rate of 44,100 frames/second. This gives a frame size of 4 bytes ( $2 * 2$ ), and a second's worth occupies  $2 * 2 * 44100$  bytes (176,400 bytes).

Module `aifc` defines the following function:

`aifc.open` (*file* [, *mode* ])

Open an AIFF or AIFF-C file and return an object instance with methods that are described below. The argument *file* is either a string naming a file or a file object. *mode* must be `'r'` or `'rb'` when the file must be opened for reading, or `'w'` or `'wb'` when the file must be opened for writing. If omitted, `file.mode` is used if it exists, otherwise `'rb'` is used. When used for writing, the file object should be seekable, unless you know ahead of time how many samples you are going to write in total and use `writeframesraw()` and `setnframes()`.

Objects returned by `open()` when a file is opened for reading have the following methods:

`aifc.getnchannels` ()

Return the number of audio channels (1 for mono, 2 for stereo).

`aifc.getsampwidth` ()

Return the size in bytes of individual samples.

**aifc.getframerate()**  
Return the sampling rate (number of audio frames per second).

**aifc.getnframes()**  
Return the number of audio frames in the file.

**aifc.getcomptype()**  
Return a four-character string describing the type of compression used in the audio file. For AIFF files, the returned value is 'NONE'.

**aifc.getcompname()**  
Return a human-readable description of the type of compression used in the audio file. For AIFF files, the returned value is 'not compressed'.

**aifc.getparams()**  
Return a tuple consisting of all of the above values in the above order.

**aifc.getmarkers()**  
Return a list of markers in the audio file. A marker consists of a tuple of three elements. The first is the mark ID (an integer), the second is the mark position in frames from the beginning of the data (an integer), the third is the name of the mark (a string).

**aifc.getmark(*id*)**  
Return the tuple as described in `getmarkers()` for the mark with the given *id*.

**aifc.readframes(*nframes*)**  
Read and return the next *nframes* frames from the audio file. The returned data is a string containing for each frame the uncompressed samples of all channels.

**aifc.rewind()**  
Rewind the read pointer. The next `readframes()` will start from the beginning.

**aifc.setpos(*pos*)**  
Seek to the specified frame number.

**aifc.tell()**  
Return the current frame number.

**aifc.close()**  
Close the AIFF file. After calling this method, the object can no longer be used.

Objects returned by `open()` when a file is opened for writing have all the above methods, except for `readframes()` and `setpos()`. In addition the following methods exist. The `get*()` methods can only be called after the corresponding `set*()` methods have been called. Before the first `writeframes()` or `writeframesraw()`, all parameters except for the number of frames must be filled in.

**aifc.aiff()**  
Create an AIFF file. The default is that an AIFF-C file is created, unless the name of the file ends in '.aiff' in which case the default is an AIFF file.

**aifc.aifc()**  
Create an AIFF-C file. The default is that an AIFF-C file is created, unless the name of the file ends in '.aiff' in which case the default is an AIFF file.

**aifc.setnchannels(*nchannels*)**  
Specify the number of channels in the audio file.

**aifc.setsampwidth(*width*)**  
Specify the size in bytes of audio samples.

**aifc.setframerate(*rate*)**  
Specify the sampling frequency in frames per second.

`aifc.setnframes` (*nframes*)

Specify the number of frames that are to be written to the audio file. If this parameter is not set, or not set correctly, the file needs to support seeking.

`aifc.setcomptype` (*type, name*)

Specify the compression type. If not specified, the audio data will not be compressed. In AIFF files, compression is not possible. The name parameter should be a human-readable description of the compression type, the type parameter should be a four-character string. Currently the following compression types are supported: NONE, ULAW, ALAW, G722.

`aifc.setparams` (*nchannels, sampwidth, framerate, comptype, compname*)

Set all the above parameters at once. The argument is a tuple consisting of the various parameters. This means that it is possible to use the result of a `getparams()` call as argument to `setparams()`.

`aifc.setmark` (*id, pos, name*)

Add a mark with the given id (larger than 0), and the given name at the given position. This method can be called at any time before `close()`.

`aifc.tell` ()

Return the current write position in the output file. Useful in combination with `setmark()`.

`aifc.writeframes` (*data*)

Write data to the output file. This method can only be called after the audio file parameters have been set.

`aifc.writeframesraw` (*data*)

Like `writeframes()`, except that the header of the audio file is not updated.

`aifc.close` ()

Close the AIFF file. The header of the file is updated to reflect the actual size of the audio data. After calling this method, the object can no longer be used.

## 21.4 sunau — Read and write Sun AU files

**Source code:** [Lib/sunau.py](#)

The `sunau` module provides a convenient interface to the Sun AU sound format. Note that this module is interface-compatible with the modules `aifc` and `wave`.

An audio file consists of a header followed by the data. The fields of the header are:

Field	Contents
magic word	The four bytes <code>.snd</code> .
header size	Size of the header, including info, in bytes.
data size	Physical size of the data, in bytes.
encoding	Indicates how the audio samples are encoded.
sample rate	The sampling rate.
# of channels	The number of channels in the samples.
info	ASCII string giving a description of the audio file (padded with null bytes).

Apart from the info field, all header fields are 4 bytes in size. They are all 32-bit unsigned integers encoded in big-endian byte order.

The `sunau` module defines the following functions:

`sunau.open` (*file, mode*)

If *file* is a string, open the file by that name, otherwise treat it as a seekable file-like object. *mode* can be any of  
 'r' Read only mode.

'w' Write only mode.

Note that it does not allow read/write files.

A *mode* of 'r' returns a `AU_read` object, while a *mode* of 'w' or 'wb' returns a `AU_write` object.

`sunau.openfp` (*file, mode*)

A synonym for `open()`, maintained for backwards compatibility.

The `sunau` module defines the following exception:

**exception** `sunau.Error`

An error raised when something is impossible because of Sun AU specs or implementation deficiency.

The `sunau` module defines the following data items:

`sunau.AUDIO_FILE_MAGIC`

An integer every valid Sun AU file begins with, stored in big-endian form. This is the string `.snd` interpreted as an integer.

`sunau.AUDIO_FILE_ENCODING_MULAW_8`

`sunau.AUDIO_FILE_ENCODING_LINEAR_8`

`sunau.AUDIO_FILE_ENCODING_LINEAR_16`

`sunau.AUDIO_FILE_ENCODING_LINEAR_24`

`sunau.AUDIO_FILE_ENCODING_LINEAR_32`

`sunau.AUDIO_FILE_ENCODING_ALAW_8`

Values of the encoding field from the AU header which are supported by this module.

`sunau.AUDIO_FILE_ENCODING_FLOAT`

`sunau.AUDIO_FILE_ENCODING_DOUBLE`

`sunau.AUDIO_FILE_ENCODING_ADPCM_G721`

`sunau.AUDIO_FILE_ENCODING_ADPCM_G722`

`sunau.AUDIO_FILE_ENCODING_ADPCM_G723_3`

`sunau.AUDIO_FILE_ENCODING_ADPCM_G723_5`

Additional known values of the encoding field from the AU header, but which are not supported by this module.

### 21.4.1 AU\_read Objects

`AU_read` objects, as returned by `open()` above, have the following methods:

`AU_read.close()`

Close the stream, and make the instance unusable. (This is called automatically on deletion.)

`AU_read.getnchannels()`

Returns number of audio channels (1 for mono, 2 for stereo).

`AU_read.getsampwidth()`

Returns sample width in bytes.

`AU_read.getframerate()`

Returns sampling frequency.

`AU_read.getnframes()`

Returns number of audio frames.

`AU_read.getcomptype()`

Returns compression type. Supported compression types are 'ULAW', 'ALAW' and 'NONE'.

`AU_read.getcompname()`

Human-readable version of `getcomptype()`. The supported types have the respective names 'CCITT G.711 u-law', 'CCITT G.711 A-law' and 'not compressed'.

`AU_read.getparams()`  
Returns a tuple (`nchannels`, `sampwidth`, `framerate`, `nframes`, `comptype`, `compname`), equivalent to output of the `get*()` methods.

`AU_read.readframes(n)`  
Reads and returns at most `n` frames of audio, as a string of bytes. The data will be returned in linear format. If the original data is in u-LAW format, it will be converted.

`AU_read.rewind()`  
Rewind the file pointer to the beginning of the audio stream.

The following two methods define a term “position” which is compatible between them, and is otherwise implementation dependent.

`AU_read.setpos(pos)`  
Set the file pointer to the specified position. Only values returned from `tell()` should be used for `pos`.

`AU_read.tell()`  
Return current file pointer position. Note that the returned value has nothing to do with the actual position in the file.

The following two functions are defined for compatibility with the `aifc`, and don’t do anything interesting.

`AU_read.getmarkers()`  
Returns None.

`AU_read.getmark(id)`  
Raise an error.

## 21.4.2 AU\_write Objects

`AU_write` objects, as returned by `open()` above, have the following methods:

`AU_write.setnchannels(n)`  
Set the number of channels.

`AU_write.setsampwidth(n)`  
Set the sample width (in bytes.)

`AU_write.setframerate(n)`  
Set the frame rate.

`AU_write.setnframes(n)`  
Set the number of frames. This can be later changed, when and if more frames are written.

`AU_write.setcomptype(type, name)`  
Set the compression type and description. Only ‘NONE’ and ‘ULAW’ are supported on output.

`AU_write.setparams(tuple)`  
The *tuple* should be (`nchannels`, `sampwidth`, `framerate`, `nframes`, `comptype`, `compname`), with values valid for the `set*()` methods. Set all parameters.

`AU_write.tell()`  
Return current position in the file, with the same disclaimer for the `AU_read.tell()` and `AU_read.setpos()` methods.

`AU_write.writeframesraw(data)`  
Write audio frames, without correcting `nframes`.

`AU_write.writeframes(data)`  
Write audio frames and make sure `nframes` is correct.

`AU_write.close()`

Make sure *nframes* is correct, and close the file.

This method is called upon deletion.

Note that it is invalid to set any parameters after calling `writeframes()` or `writeframesraw()`.

## 21.5 wave — Read and write WAV files

**Source code:** [Lib/wave.py](#)

---

The `wave` module provides a convenient interface to the WAV sound format. It does not support compression/decompression, but it does support mono/stereo.

The `wave` module defines the following function and exception:

`wave.open(file[, mode])`

If *file* is a string, open the file by that name, otherwise treat it as a seekable file-like object. *mode* can be any of

'r', 'rb' Read only mode.

'w', 'wb' Write only mode.

Note that it does not allow read/write WAV files.

A *mode* of 'r' or 'rb' returns a `Wave_read` object, while a *mode* of 'w' or 'wb' returns a `Wave_write` object. If *mode* is omitted and a file-like object is passed as *file*, `file.mode` is used as the default value for *mode* (the 'b' flag is still added if necessary).

If you pass in a file-like object, the wave object will not close it when its `close()` method is called; it is the caller's responsibility to close the file object.

`wave.openfp(file, mode)`

A synonym for `open()`, maintained for backwards compatibility.

**exception** `wave.Error`

An error raised when something is impossible because it violates the WAV specification or hits an implementation deficiency.

### 21.5.1 Wave\_read Objects

`Wave_read` objects, as returned by `open()`, have the following methods:

`Wave_read.close()`

Close the stream if it was opened by `wave`, and make the instance unusable. This is called automatically on object collection.

`Wave_read.getnchannels()`

Returns number of audio channels (1 for mono, 2 for stereo).

`Wave_read.getsampwidth()`

Returns sample width in bytes.

`Wave_read.getframerate()`

Returns sampling frequency.

`Wave_read.getnframes()`

Returns number of audio frames.

`Wave_read.getcomptype()`  
Returns compression type ('NONE' is the only supported type).

`Wave_read.getcompname()`  
Human-readable version of `getcomptype()`. Usually 'not compressed' parallels 'NONE'.

`Wave_read.getparams()`  
Returns a tuple (`nchannels`, `sampwidth`, `framerate`, `nframes`, `comptype`, `compname`), equivalent to output of the `get*()` methods.

`Wave_read.readframes(n)`  
Reads and returns at most `n` frames of audio, as a string of bytes.

`Wave_read.rewind()`  
Rewind the file pointer to the beginning of the audio stream.

The following two methods are defined for compatibility with the `aifc` module, and don't do anything interesting.

`Wave_read.getmarkers()`  
Returns None.

`Wave_read.getmark(id)`  
Raise an error.

The following two methods define a term "position" which is compatible between them, and is otherwise implementation dependent.

`Wave_read.setpos(pos)`  
Set the file pointer to the specified position.

`Wave_read.tell()`  
Return current file pointer position.

## 21.5.2 Wave\_write Objects

`Wave_write` objects, as returned by `open()`, have the following methods:

`Wave_write.close()`  
Make sure `nframes` is correct, and close the file if it was opened by `wave`. This method is called upon object collection.

`Wave_write.setnchannels(n)`  
Set the number of channels.

`Wave_write.setsampwidth(n)`  
Set the sample width to `n` bytes.

`Wave_write.setframerate(n)`  
Set the frame rate to `n`.

`Wave_write.setnframes(n)`  
Set the number of frames to `n`. This will be changed later if more frames are written.

`Wave_write.setcomptype(type, name)`  
Set the compression type and description. At the moment, only compression type NONE is supported, meaning no compression.

`Wave_write.setparams(tuple)`  
The *tuple* should be (`nchannels`, `sampwidth`, `framerate`, `nframes`, `comptype`, `compname`), with values valid for the `set*()` methods. Sets all parameters.

`Wave_write.tell()`

Return current position in the file, with the same disclaimer for the `Wave_read.tell()` and `Wave_read.setpos()` methods.

`Wave_write.writeframesraw(data)`

Write audio frames, without correcting *nframes*.

`Wave_write.writeframes(data)`

Write audio frames and make sure *nframes* is correct.

Note that it is invalid to set any parameters after calling `writeframes()` or `writeframesraw()`, and any attempt to do so will raise `wave.Error`.

## 21.6 chunk — Read IFF chunked data

This module provides an interface for reading files that use EA IFF 85 chunks.<sup>1</sup> This format is used in at least the Audio Interchange File Format (AIFF/AIFF-C) and the Real Media File Format (RMFF). The WAVE audio file format is closely related and can also be read using this module.

A chunk has the following structure:

Offset	Length	Contents
0	4	Chunk ID
4	4	Size of chunk in big-endian byte order, not including the header
8	<i>n</i>	Data bytes, where <i>n</i> is the size given in the preceding field
8 + <i>n</i>	0 or 1	Pad byte needed if <i>n</i> is odd and chunk alignment is used

The ID is a 4-byte string which identifies the type of chunk.

The size field (a 32-bit value, encoded using big-endian byte order) gives the size of the chunk data, not including the 8-byte header.

Usually an IFF-type file consists of one or more chunks. The proposed usage of the `Chunk` class defined here is to instantiate an instance at the start of each chunk and read from the instance until it reaches the end, after which a new instance can be instantiated. At the end of the file, creating a new instance will fail with a `EOFError` exception.

**class** `chunk.Chunk` (*file*[, *align*, *bigendian*, *inclheader* ])

Class which represents a chunk. The *file* argument is expected to be a file-like object. An instance of this class is specifically allowed. The only method that is needed is `read()`. If the methods `seek()` and `tell()` are present and don't raise an exception, they are also used. If these methods are present and raise an exception, they are expected to not have altered the object. If the optional argument *align* is true, chunks are assumed to be aligned on 2-byte boundaries. If *align* is false, no alignment is assumed. The default value is true. If the optional argument *bigendian* is false, the chunk size is assumed to be in little-endian order. This is needed for WAVE audio files. The default value is true. If the optional argument *inclheader* is true, the size given in the chunk header includes the size of the header. The default value is false.

A `Chunk` object supports the following methods:

**getname()**

Returns the name (ID) of the chunk. This is the first 4 bytes of the chunk.

**getsize()**

Returns the size of the chunk.

**close()**

Close and skip to the end of the chunk. This does not close the underlying file.

The remaining methods will raise `IOError` if called after the `close()` method has been called.

<sup>1</sup> "EA IFF 85" Standard for Interchange Format Files, Jerry Morrison, Electronic Arts, January 1985.

**isatty()**

Returns False.

**seek** (*pos*[, *whence* ])Set the chunk's current position. The *whence* argument is optional and defaults to 0 (absolute file positioning); other values are 1 (seek relative to the current position) and 2 (seek relative to the file's end). There is no return value. If the underlying file does not allow seek, only forward seeks are allowed.**tell()**

Return the current position into the chunk.

**read** ([*size* ])Read at most *size* bytes from the chunk (less if the read hits the end of the chunk before obtaining *size* bytes). If the *size* argument is negative or omitted, read all data until the end of the chunk. The bytes are returned as a string object. An empty string is returned when the end of the chunk is encountered immediately.**skip()**Skip to the end of the chunk. All further calls to `read()` for the chunk will return "". If you are not interested in the contents of the chunk, this method should be called so that the file points to the start of the next chunk.

## 21.7 colorsys — Conversions between color systems

**Source code:** [Lib/colors.py](#)

The `colorsys` module defines bidirectional conversions of color values between colors expressed in the RGB (Red Green Blue) color space used in computer monitors and three other coordinate systems: YIQ, HLS (Hue Lightness Saturation) and HSV (Hue Saturation Value). Coordinates in all of these color spaces are floating point values. In the YIQ space, the Y coordinate is between 0 and 1, but the I and Q coordinates can be positive or negative. In all other spaces, the coordinates are all between 0 and 1.

**See Also:**

More information about color spaces can be found at <http://www.poynton.com/ColorFAQ.html> and <http://www.cambridgeincolour.com/tutorials/color-spaces.htm>.

The `colorsys` module defines the following functions:

`colorsys.rgb_to_yiq(r, g, b)`

Convert the color from RGB coordinates to YIQ coordinates.

`colorsys.yiq_to_rgb(y, i, q)`

Convert the color from YIQ coordinates to RGB coordinates.

`colorsys.rgb_to_hls(r, g, b)`

Convert the color from RGB coordinates to HLS coordinates.

`colorsys.hls_to_rgb(h, l, s)`

Convert the color from HLS coordinates to RGB coordinates.

`colorsys.rgb_to_hsv(r, g, b)`

Convert the color from RGB coordinates to HSV coordinates.

`colorsys.hsv_to_rgb(h, s, v)`

Convert the color from HSV coordinates to RGB coordinates.

Example:

```
>>> import colorsys
>>> colorsys.rgb_to_hsv(.3, .4, .2)
(0.25, 0.5, 0.4)
>>> colorsys.hsv_to_rgb(0.25, 0.5, 0.4)
(0.3, 0.4, 0.2)
```

## 21.8 `imghdr` — Determine the type of an image

Source code: [Lib/imghdr.py](#)

---

The `imghdr` module determines the type of image contained in a file or byte stream.

The `imghdr` module defines the following function:

`imghdr.what` (*filename*[, *h*])

Tests the image data contained in the file named by *filename*, and returns a string describing the image type. If optional *h* is provided, the *filename* is ignored and *h* is assumed to contain the byte stream to test.

The following image types are recognized, as listed below with the return value from `what()`:

Value	Image format
'rgb'	SGI ImgLib Files
'gif'	GIF 87a and 89a Files
'pbm'	Portable Bitmap Files
'pgm'	Portable Graymap Files
'ppm'	Portable Pixmap Files
'tiff'	TIFF Files
'rast'	Sun Raster Files
'xbm'	X Bitmap Files
'jpeg'	JPEG data in JFIF or Exif formats
'bmp'	BMP files
'png'	Portable Network Graphics

New in version 2.5: Exif detection. You can extend the list of file types `imghdr` can recognize by appending to this variable:

`imghdr.tests`

A list of functions performing the individual tests. Each function takes two arguments: the byte-stream and an open file-like object. When `what()` is called with a byte-stream, the file-like object will be `None`.

The test function should return a string describing the image type if the test succeeded, or `None` if it failed.

Example:

```
>>> import imghdr
>>> imghdr.what('/tmp/bass.gif')
'gif'
```

## 21.9 `sndhdr` — Determine type of sound file

Source code: [Lib/sndhdr.py](#)

---

The `sndhdr` provides utility functions which attempt to determine the type of sound data which is in a file. When these functions are able to determine what type of sound data is stored in a file, they return a tuple (`type`, `sampling_rate`, `channels`, `frames`, `bits_per_sample`). The value for `type` indicates the data type and will be one of the strings `'aifc'`, `'aiff'`, `'au'`, `'hcom'`, `'sndr'`, `'sndt'`, `'voc'`, `'wav'`, `'8svx'`, `'sb'`, `'ub'`, or `'ul'`. The `sampling_rate` will be either the actual value or 0 if unknown or difficult to decode. Similarly, `channels` will be either the number of channels or 0 if it cannot be determined or if the value is difficult to decode. The value for `frames` will be either the number of frames or -1. The last item in the tuple, `bits_per_sample`, will either be the sample size in bits or `'A'` for A-LAW or `'U'` for u-LAW.

`sndhdr.what(filename)`

Determines the type of sound data stored in the file `filename` using `whathdr()`. If it succeeds, returns a tuple as described above, otherwise `None` is returned.

`sndhdr.whathdr(filename)`

Determines the type of sound data stored in a file based on the file header. The name of the file is given by `filename`. This function returns a tuple as described above on success, or `None`.

## 21.10 ossaudiodev — Access to OSS-compatible audio devices

*Platforms:* Linux, FreeBSD

New in version 2.3. This module allows you to access the OSS (Open Sound System) audio interface. OSS is available for a wide range of open-source and commercial Unices, and is the standard audio interface for Linux and recent versions of FreeBSD.

**See Also:**

**Open Sound System Programmer's Guide** the official documentation for the OSS C API

The module defines a large number of constants supplied by the OSS device driver; see `<sys/soundcard.h>` on either Linux or FreeBSD for a listing.

`ossaudiodev` defines the following variables and functions:

**exception** `ossaudiodev.OSSAudioError`

This exception is raised on certain errors. The argument is a string describing what went wrong.

(If `ossaudiodev` receives an error from a system call such as `open()`, `write()`, or `ioctl()`, it raises `IOError`. Errors detected directly by `ossaudiodev` result in `OSSAudioError`.)

(For backwards compatibility, the exception class is also available as `ossaudiodev.error`.)

`ossaudiodev.open(mode)`

`ossaudiodev.open(device, mode)`

Open an audio device and return an OSS audio device object. This object supports many file-like methods, such as `read()`, `write()`, and `fileno()` (although there are subtle differences between conventional Unix read/write semantics and those of OSS audio devices). It also supports a number of audio-specific methods; see below for the complete list of methods.

`device` is the audio device filename to use. If it is not specified, this module first looks in the environment variable `AUDIODEV` for a device to use. If not found, it falls back to `/dev/dsp`.

`mode` is one of `'r'` for read-only (record) access, `'w'` for write-only (playback) access and `'rw'` for both. Since many sound cards only allow one process to have the recorder or player open at a time, it is a good idea to open the device only for the activity needed. Further, some sound cards are half-duplex: they can be opened for reading or writing, but not both at once.

Note the unusual calling syntax: the *first* argument is optional, and the second is required. This is a historical artifact for compatibility with the older `linuxaudiodev` module which `ossaudiodev` supersedes.

`ossaudiodev.openmixer([device])`

Open a mixer device and return an OSS mixer device object. *device* is the mixer device filename to use. If it is not specified, this module first looks in the environment variable `MIXERDEV` for a device to use. If not found, it falls back to `/dev/mixer`.

### 21.10.1 Audio Device Objects

Before you can write to or read from an audio device, you must call three methods in the correct order:

1. `setfmt()` to set the output format
2. `channels()` to set the number of channels
3. `speed()` to set the sample rate

Alternately, you can use the `setparameters()` method to set all three audio parameters at once. This is more convenient, but may not be as flexible in all cases.

The audio device objects returned by `open()` define the following methods and (read-only) attributes:

`oss_audio_device.close()`

Explicitly close the audio device. When you are done writing to or reading from an audio device, you should explicitly close it. A closed device cannot be used again.

`oss_audio_device.fileno()`

Return the file descriptor associated with the device.

`oss_audio_device.read(size)`

Read *size* bytes from the audio input and return them as a Python string. Unlike most Unix device drivers, OSS audio devices in blocking mode (the default) will block `read()` until the entire requested amount of data is available.

`oss_audio_device.write(data)`

Write the Python string *data* to the audio device and return the number of bytes written. If the audio device is in blocking mode (the default), the entire string is always written (again, this is different from usual Unix device semantics). If the device is in non-blocking mode, some data may not be written —see `writeall()`.

`oss_audio_device.writeall(data)`

Write the entire Python string *data* to the audio device: waits until the audio device is able to accept data, writes as much data as it will accept, and repeats until *data* has been completely written. If the device is in blocking mode (the default), this has the same effect as `write()`; `writeall()` is only useful in non-blocking mode. Has no return value, since the amount of data written is always equal to the amount of data supplied.

The following methods each map to exactly one `ioctl()` system call. The correspondence is obvious: for example, `setfmt()` corresponds to the `SNDCTL_DSP_SETFMT` `ioctl`, and `sync()` to `SNDCTL_DSP_SYNC` (this can be useful when consulting the OSS documentation). If the underlying `ioctl()` fails, they all raise `IOError`.

`oss_audio_device.nonblock()`

Put the device into non-blocking mode. Once in non-blocking mode, there is no way to return it to blocking mode.

`oss_audio_device.getfmts()`

Return a bitmask of the audio output formats supported by the soundcard. Some of the formats supported by OSS are:

Format	Description
AFMT_MU_LAW	a logarithmic encoding (used by Sun .au files and /dev/audio)
AFMT_A_LAW	a logarithmic encoding
AFMT_IMA_ADPCM	a 4:1 compressed format defined by the Interactive Multimedia Association
AFMT_U8	Unsigned, 8-bit audio
AFMT_S16_LE	Signed, 16-bit audio, little-endian byte order (as used by Intel processors)
AFMT_S16_BE	Signed, 16-bit audio, big-endian byte order (as used by 68k, PowerPC, Sparc)
AFMT_S8	Signed, 8 bit audio
AFMT_U16_LE	Unsigned, 16-bit little-endian audio
AFMT_U16_BE	Unsigned, 16-bit big-endian audio

Consult the OSS documentation for a full list of audio formats, and note that most devices support only a subset of these formats. Some older devices only support `AFMT_U8`; the most common format used today is `AFMT_S16_LE`.

`oss_audio_device.setfmt` (*format*)

Try to set the current audio format to *format*—see `getfmts()` for a list. Returns the audio format that the device was set to, which may not be the requested format. May also be used to return the current audio format—do this by passing an “audio format” of `AFMT_QUERY`.

`oss_audio_device.channels` (*nchannels*)

Set the number of output channels to *nchannels*. A value of 1 indicates monophonic sound, 2 stereophonic. Some devices may have more than 2 channels, and some high-end devices may not support mono. Returns the number of channels the device was set to.

`oss_audio_device.speed` (*samplerate*)

Try to set the audio sampling rate to *samplerate* samples per second. Returns the rate actually set. Most sound devices don’t support arbitrary sampling rates. Common rates are:

Rate	Description
8000	default rate for /dev/audio
11025	speech recording
22050	
44100	CD quality audio (at 16 bits/sample and 2 channels)
96000	DVD quality audio (at 24 bits/sample)

`oss_audio_device.sync` ()

Wait until the sound device has played every byte in its buffer. (This happens implicitly when the device is closed.) The OSS documentation recommends closing and re-opening the device rather than using `sync()`.

`oss_audio_device.reset` ()

Immediately stop playing or recording and return the device to a state where it can accept commands. The OSS documentation recommends closing and re-opening the device after calling `reset()`.

`oss_audio_device.post` ()

Tell the driver that there is likely to be a pause in the output, making it possible for the device to handle the pause more intelligently. You might use this after playing a spot sound effect, before waiting for user input, or before doing disk I/O.

The following convenience methods combine several ioctls, or one ioctl and some simple calculations.

`oss_audio_device.setparameters` (*format*, *nchannels*, *samplerate* [, *strict=False* ])

Set the key audio sampling parameters—sample format, number of channels, and sampling rate—in one method call. *format*, *nchannels*, and *samplerate* should be as specified in the `setfmt()`, `channels()`, and `speed()` methods. If *strict* is true, `setparameters()` checks to see if each parameter was actually set to the requested value, and raises `OSSAudioError` if not. Returns a tuple (*format*, *nchannels*, *samplerate*) indicating the parameter values that were actually set by the device driver (i.e., the same as the return values of `setfmt()`, `channels()`, and `speed()`).

For example,

```
(fmt, channels, rate) = dsp.setparameters(fmt, channels, rate)
```

is equivalent to

```
fmt = dsp.setfmt(fmt)
channels = dsp.channels(channels)
rate = dsp.rate(channels)
```

`oss_audio_device.bufsize()`

Returns the size of the hardware buffer, in samples.

`oss_audio_device.obufcount()`

Returns the number of samples that are in the hardware buffer yet to be played.

`oss_audio_device.obuffree()`

Returns the number of samples that could be queued into the hardware buffer to be played without blocking.

Audio device objects also support several read-only attributes:

`oss_audio_device.closed`

Boolean indicating whether the device has been closed.

`oss_audio_device.name`

String containing the name of the device file.

`oss_audio_device.mode`

The I/O mode for the file, either "r", "rw", or "w".

## 21.10.2 Mixer Device Objects

The mixer object provides two file-like methods:

`oss_mixer_device.close()`

This method closes the open mixer device file. Any further attempts to use the mixer after this file is closed will raise an `IOError`.

`oss_mixer_device.fileno()`

Returns the file handle number of the open mixer device file.

The remaining methods are specific to audio mixing:

`oss_mixer_device.controls()`

This method returns a bitmask specifying the available mixer controls (“Control” being a specific mixable “channel”, such as `SOUND_MIXER_PCM` or `SOUND_MIXER_SYNTH`). This bitmask indicates a subset of all available mixer controls—the `SOUND_MIXER_*` constants defined at module level. To determine if, for example, the current mixer object supports a PCM mixer, use the following Python code:

```
mixer=ossaudiodev.openmixer()
if mixer.controls() & (1 << ossaudiodev.SOUND_MIXER_PCM):
    # PCM is supported
    ... code ...
```

For most purposes, the `SOUND_MIXER_VOLUME` (master volume) and `SOUND_MIXER_PCM` controls should suffice—but code that uses the mixer should be flexible when it comes to choosing mixer controls. On the Gravis Ultrasound, for example, `SOUND_MIXER_VOLUME` does not exist.

`oss_mixer_device.stereocontrols()`

Returns a bitmask indicating stereo mixer controls. If a bit is set, the corresponding control is stereo; if it is unset, the control is either monophonic or not supported by the mixer (use in combination with `controls()` to determine which).

See the code example for the `controls()` function for an example of getting data from a bitmask.

`oss_mixer_device.recontrols()`

Returns a bitmask specifying the mixer controls that may be used to record. See the code example for `controls()` for an example of reading from a bitmask.

`oss_mixer_device.get(control)`

Returns the volume of a given mixer control. The returned volume is a 2-tuple (`left_volume`, `right_volume`). Volumes are specified as numbers from 0 (silent) to 100 (full volume). If the control is monophonic, a 2-tuple is still returned, but both volumes are the same.

Raises `OSSAudioError` if an invalid control was is specified, or `IOError` if an unsupported control is specified.

`oss_mixer_device.set(control, (left, right))`

Sets the volume for a given mixer control to (`left`, `right`). `left` and `right` must be ints and between 0 (silent) and 100 (full volume). On success, the new volume is returned as a 2-tuple. Note that this may not be exactly the same as the volume specified, because of the limited resolution of some soundcard's mixers.

Raises `OSSAudioError` if an invalid mixer control was specified, or if the specified volumes were out-of-range.

`oss_mixer_device.get_recsrc()`

This method returns a bitmask indicating which control(s) are currently being used as a recording source.

`oss_mixer_device.set_recsrc(bitmask)`

Call this function to specify a recording source. Returns a bitmask indicating the new recording source (or sources) if successful; raises `IOError` if an invalid source was specified. To set the current recording source to the microphone input:

```
mixer.setrecsrc (1 << ossaudiodev.SOUND_MIXER_MIC)
```



# INTERNATIONALIZATION

The modules described in this chapter help you write software that is independent of language and locale by providing mechanisms for selecting a language to be used in program messages or by tailoring output to match local conventions.

The list of modules described in this chapter is:

## 22.1 `gettext` — Multilingual internationalization services

**Source code:** `Lib/gettext.py`

---

The `gettext` module provides internationalization (I18N) and localization (L10N) services for your Python modules and applications. It supports both the GNU `gettext` message catalog API and a higher level, class-based API that may be more appropriate for Python files. The interface described below allows you to write your module and application messages in one natural language, and provide a catalog of translated messages for running under different natural languages.

Some hints on localizing your Python modules and applications are also given.

### 22.1.1 GNU `gettext` API

The `gettext` module defines the following API, which is very similar to the GNU `gettext` API. If you use this API you will affect the translation of your entire application globally. Often this is what you want if your application is monolingual, with the choice of language dependent on the locale of your user. If you are localizing a Python module, or if your application needs to switch languages on the fly, you probably want to use the class-based API instead.

`gettext.bindtextdomain` (*domain* [, *localedir* ])

Bind the *domain* to the locale directory *localedir*. More concretely, `gettext` will look for binary `.mo` files for the given domain using the path (on Unix): `localedir/language/LC_MESSAGES/domain.mo`, where *languages* is searched for in the environment variables `LANGUAGE`,

`LC_ALL`, `LC_MESSAGES`, and `LANG` respectively.

If *localedir* is omitted or `None`, then the current binding for *domain* is returned. <sup>1</sup>

`gettext.bind_textdomain_codeset` (*domain* [, *codeset* ])

Bind the *domain* to *codeset*, changing the encoding of strings returned by the `gettext()` family of functions. If *codeset* is omitted, then the current binding is returned. New in version 2.4.

---

<sup>1</sup> The default locale directory is system dependent; for example, on RedHat Linux it is `/usr/share/locale`, but on Solaris it is `/usr/lib/locale`. The `gettext` module does not try to support these system dependent defaults; instead its default is `sys.prefix/share/locale`. For this reason, it is always best to call `bindtextdomain()` with an explicit absolute path at the start of your application.

`gettext.textdomain([domain])`

Change or query the current global domain. If *domain* is `None`, then the current global domain is returned, otherwise the global domain is set to *domain*, which is returned.

`gettext.gettext(message)`

Return the localized translation of *message*, based on the current global domain, language, and locale directory. This function is usually aliased as `_()` in the local namespace (see examples below).

`gettext.lgettext(message)`

Equivalent to `gettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`. New in version 2.4.

`gettext.dgettext(domain, message)`

Like `gettext()`, but look the message up in the specified *domain*.

`gettext.ldgettext(domain, message)`

Equivalent to `dgettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`. New in version 2.4.

`gettext.ngettext(singular, plural, n)`

Like `gettext()`, but consider plural forms. If a translation is found, apply the plural formula to *n*, and return the resulting message (some languages have more than two plural forms). If no translation is found, return *singular* if *n* is 1; return *plural* otherwise.

The Plural formula is taken from the catalog header. It is a C or Python expression that has a free variable *n*; the expression evaluates to the index of the plural in the catalog. See the GNU `gettext` documentation for the precise syntax to be used in `.po` files and the formulas for a variety of languages. New in version 2.3.

`gettext.lngettext(singular, plural, n)`

Equivalent to `ngettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`. New in version 2.4.

`gettext.dngettext(domain, singular, plural, n)`

Like `ngettext()`, but look the message up in the specified *domain*. New in version 2.3.

`gettext.ldngettext(domain, singular, plural, n)`

Equivalent to `dngettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`. New in version 2.4.

Note that GNU `gettext` also defines a `dcgettext()` method, but this was deemed not useful and so it is currently unimplemented.

Here's an example of typical usage for this API:

```
import gettext
gettext.bindtextdomain('myapplication', '/path/to/my/language/directory')
gettext.textdomain('myapplication')
_ = gettext.gettext
# ...
print _('This is a translatable string.')
```

## 22.1.2 Class-based API

The class-based API of the `gettext` module gives you more flexibility and greater convenience than the GNU `gettext` API. It is the recommended way of localizing your Python applications and modules. `gettext` defines a “translations” class which implements the parsing of GNU `.mo` format files, and has methods for returning either standard 8-bit strings or Unicode strings. Instances of this “translations” class can also install themselves in the built-in namespace as the function `_()`.

```
gettext.find(domain[, locale_dir[, languages[, all]]])
```

This function implements the standard `.mo` file search algorithm. It takes a *domain*, identical to what `textdomain()` takes. Optional *locale\_dir* is as in `bindtextdomain()`. Optional *languages* is a list of strings, where each string is a language code.

If *locale\_dir* is not given, then the default system locale directory is used.<sup>2</sup> If *languages* is not given, then the following environment variables are searched: `LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, and

`LANG`. The first one returning a non-empty value is used for the *languages* variable. The environment variables should contain a colon separated list of languages, which will be split on the colon to produce the expected list of language code strings.

`find()` then expands and normalizes the languages, and then iterates through them, searching for an existing file built of these components:

```
locale_dir/language/LC_MESSAGES/domain.mo
```

The first such file name that exists is returned by `find()`. If no such file is found, then `None` is returned. If *all* is given, it returns a list of all file names, in the order in which they appear in the languages list or the environment variables.

```
gettext.translation(domain[, locale_dir[, languages[, class_[, fallback[, codeset]]]])
```

Return a `Translations` instance based on the *domain*, *locale\_dir*, and *languages*, which are first passed to `find()` to get a list of the associated `.mo` file paths. Instances with identical `.mo` file names are cached. The actual class instantiated is either *class\_* if provided, otherwise `GNUTranslations`. The class's constructor must take a single file object argument. If provided, *codeset* will change the charset used to encode translated strings.

If multiple files are found, later files are used as fallbacks for earlier ones. To allow setting the fallback, `copy.copy()` is used to clone each translation object from the cache; the actual instance data is still shared with the cache.

If no `.mo` file is found, this function raises `IOError` if *fallback* is false (which is the default), and returns a `NullTranslations` instance if *fallback* is true. Changed in version 2.4: Added the *codeset* parameter.

```
gettext.install(domain[, locale_dir[, unicode[, codeset[, names]]])
```

This installs the function `__()` in Python's builtins namespace, based on *domain*, *locale\_dir*, and *codeset* which are passed to the function `translation()`. The *unicode* flag is passed to the resulting translation object's `install()` method.

For the *names* parameter, please see the description of the translation object's `install()` method.

As seen below, you usually mark the strings in your application that are candidates for translation, by wrapping them in a call to the `__()` function, like this:

```
print __('This string will be translated.')
```

For convenience, you want the `__()` function to be installed in Python's builtins namespace, so it is easily accessible in all modules of your application. Changed in version 2.4: Added the *codeset* parameter. Changed in version 2.5: Added the *names* parameter.

## The NullTranslations class

Translation classes are what actually implement the translation of original source file message strings to translated message strings. The base class used by all translation classes is `NullTranslations`; this provides the basic interface you can use to write your own specialized translation classes. Here are the methods of `NullTranslations`:

<sup>2</sup> See the footnote for `bindtextdomain()` above.

**class** `gettext.NullTranslations` (`[fp]`)

Takes an optional file object `fp`, which is ignored by the base class. Initializes “protected” instance variables `_info` and `_charset` which are set by derived classes, as well as `_fallback`, which is set through `add_fallback()`. It then calls `self._parse(fp)` if `fp` is not `None`.

**`_parse`** (`fp`)

No-op’d in the base class, this method takes file object `fp`, and reads the data from the file, initializing its message catalog. If you have an unsupported message catalog file format, you should override this method to parse your format.

**`add_fallback`** (`fallback`)

Add `fallback` as the fallback object for the current translation object. A translation object should consult the fallback if it cannot provide a translation for a given message.

**`gettext`** (`message`)

If a fallback has been set, forward `gettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes.

**`lgettext`** (`message`)

If a fallback has been set, forward `lgettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes. New in version 2.4.

**`ugettext`** (`message`)

If a fallback has been set, forward `ugettext()` to the fallback. Otherwise, return the translated message as a Unicode string. Overridden in derived classes.

**`ngettext`** (`singular`, `plural`, `n`)

If a fallback has been set, forward `ngettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes. New in version 2.3.

**`lngettext`** (`singular`, `plural`, `n`)

If a fallback has been set, forward `lngettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes. New in version 2.4.

**`ungettext`** (`singular`, `plural`, `n`)

If a fallback has been set, forward `ungettext()` to the fallback. Otherwise, return the translated message as a Unicode string. Overridden in derived classes. New in version 2.3.

**`info`** ()

Return the “protected” `_info` variable.

**`charset`** ()

Return the “protected” `_charset` variable.

**`output_charset`** ()

Return the “protected” `_output_charset` variable, which defines the encoding used to return translated messages. New in version 2.4.

**`set_output_charset`** (`charset`)

Change the “protected” `_output_charset` variable, which defines the encoding used to return translated messages. New in version 2.4.

**`install`** (`[unicode[, names]]`)

If the `unicode` flag is false, this method installs `self.gettext()` into the built-in namespace, binding it to `_`. If `unicode` is true, it binds `self.ugettext()` instead. By default, `unicode` is false.

If the `names` parameter is given, it must be a sequence containing the names of functions you want to install in the builtins namespace in addition to `_()`. Supported names are ‘`gettext`’ (bound to `self.gettext()` or `self.ugettext()` according to the `unicode` flag), ‘`ngettext`’ (bound to `self.ngettext()` or `self.ungettext()` according to the `unicode` flag), ‘`lgettext`’ and ‘`lngettext`’.

Note that this is only one way, albeit the most convenient way, to make the `_()` function available to your application. Because it affects the entire application globally, and specifically the built-in namespace, localized modules should never install `_()`. Instead, they should use this code to make `_()` available to their module:

```
import gettext
t = gettext.translation('mymodule', ...)
_ = t.gettext
```

This puts `_()` only in the module's global namespace and so only affects calls within this module. Changed in version 2.5: Added the *names* parameter.

## The GNUTranslations class

The `gettext` module provides one additional class derived from `NullTranslations`: `GNUTranslations`. This class overrides `_parse()` to enable reading GNU **gettext** format `.mo` files in both big-endian and little-endian format. It also coerces both message ids and message strings to Unicode.

`GNUTranslations` parses optional meta-data out of the translation catalog. It is convention with GNU **gettext** to include meta-data as the translation for the empty string. This meta-data is in **RFC 822**-style `key: value` pairs, and should contain the `Project-Id-Version` key. If the key `Content-Type` is found, then the `charset` property is used to initialize the “protected” `_charset` instance variable, defaulting to `None` if not found. If the charset encoding is specified, then all message ids and message strings read from the catalog are converted to Unicode using this encoding. The `ugettext()` method always returns a Unicode, while the `gettext()` returns an encoded 8-bit string. For the message id arguments of both methods, either Unicode strings or 8-bit strings containing only US-ASCII characters are acceptable. Note that the Unicode version of the methods (i.e. `ugettext()` and `ungettext()`) are the recommended interface to use for internationalized Python programs.

The entire set of key/value pairs are placed into a dictionary and set as the “protected” `_info` instance variable.

If the `.mo` file's magic number is invalid, or if other problems occur while reading the file, instantiating a `GNUTranslations` class can raise `IOError`.

The following methods are overridden from the base class implementation:

`GNUTranslations.gettext(message)`

Look up the *message* id in the catalog and return the corresponding message string, as an 8-bit string encoded with the catalog's charset encoding, if known. If there is no entry in the catalog for the *message* id, and a fallback has been set, the look up is forwarded to the fallback's `gettext()` method. Otherwise, the *message* id is returned.

`GNUTranslations.lgettext(message)`

Equivalent to `gettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `set_output_charset()`. New in version 2.4.

`GNUTranslations.ugettext(message)`

Look up the *message* id in the catalog and return the corresponding message string, as a Unicode string. If there is no entry in the catalog for the *message* id, and a fallback has been set, the look up is forwarded to the fallback's `ugettext()` method. Otherwise, the *message* id is returned.

`GNUTranslations.ngettext(singular, plural, n)`

Do a plural-forms lookup of a message id. *singular* is used as the message id for purposes of lookup in the catalog, while *n* is used to determine which plural form to use. The returned message string is an 8-bit string encoded with the catalog's charset encoding, if known.

If the message id is not found in the catalog, and a fallback is specified, the request is forwarded to the fallback's `ngettext()` method. Otherwise, when *n* is 1 *singular* is returned, and *plural* is returned in all other cases. New in version 2.3.

`GNUTranslations.ingettext(singular, plural, n)`

Equivalent to `gettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `set_output_charset()`. New in version 2.4.

`GNUTranslations.ungettext(singular, plural, n)`

Do a plural-forms lookup of a message id. *singular* is used as the message id for purposes of lookup in the catalog, while *n* is used to determine which plural form to use. The returned message string is a Unicode string.

If the message id is not found in the catalog, and a fallback is specified, the request is forwarded to the fallback's `ungettext()` method. Otherwise, when *n* is 1 *singular* is returned, and *plural* is returned in all other cases.

Here is an example:

```
n = len(os.listdir('.'))
cat = GNUTranslations(somefile)
message = cat.ungettext(
    'There is %(num)d file in this directory',
    'There are %(num)d files in this directory',
    n) % {'num': n}
```

New in version 2.3.

### Solaris message catalog support

The Solaris operating system defines its own binary `.mo` file format, but since no documentation can be found on this format, it is not supported at this time.

### The Catalog constructor

GNOME uses a version of the `gettext` module by James Henstridge, but this version has a slightly different API. Its documented usage was:

```
import gettext
cat = gettext.Catalog(domain, locale_dir)
_ = cat.gettext
print _('hello world')
```

For compatibility with this older module, the function `Catalog()` is an alias for the `translation()` function described above.

One difference between this module and Henstridge's: his catalog objects supported access through a mapping API, but this appears to be unused and so is not currently supported.

## 22.1.3 Internationalizing your programs and modules

Internationalization (I18N) refers to the operation by which a program is made aware of multiple languages. Localization (L10N) refers to the adaptation of your program, once internationalized, to the local language and cultural habits. In order to provide multilingual messages for your Python programs, you need to take the following steps:

1. prepare your program or module by specially marking translatable strings
2. run a suite of tools over your marked files to generate raw messages catalogs
3. create language specific translations of the message catalogs
4. use the `gettext` module so that message strings are properly translated

In order to prepare your code for I18N, you need to look at all the strings in your files. Any string that needs to be translated should be marked by wrapping it in `_( ' . . . ' )` — that is, a call to the function `_ ( )`. For example:

```
filename = 'mylog.txt'
message = _('writing a log message')
fp = open(filename, 'w')
fp.write(message)
fp.close()
```

In this example, the string `'writing a log message'` is marked as a candidate for translation, while the strings `'mylog.txt'` and `'w'` are not.

The Python distribution comes with two tools which help you generate the message catalogs once you've prepared your source code. These may or may not be available from a binary distribution, but they can be found in a source distribution, in the `Tools/i18n` directory.

The **pygettext**<sup>3</sup> program scans all your Python source code looking for the strings you previously marked as translatable. It is similar to the GNU **gettext** program except that it understands all the intricacies of Python source code, but knows nothing about C or C++ source code. You don't need GNU **gettext** unless you're also going to be translating C code (such as C extension modules).

**pygettext** generates textual Uniform-style human readable message catalog `.pot` files, essentially structured human readable files which contain every marked string in the source code, along with a placeholder for the translation strings. **pygettext** is a command line script that supports a similar command line interface as **xgettext**; for details on its use, run:

```
pygettext.py --help
```

Copies of these `.pot` files are then handed over to the individual human translators who write language-specific versions for every supported natural language. They send you back the filled in language-specific versions as a `.po` file. Using the **msgfmt.py**<sup>4</sup> program (in the `Tools/i18n` directory), you take the `.po` files from your translators and generate the machine-readable `.mo` binary catalog files. The `.mo` files are what the **gettext** module uses for the actual translation processing during run-time.

How you use the **gettext** module in your code depends on whether you are internationalizing a single module or your entire application. The next two sections will discuss each case.

## Localizing your module

If you are localizing your module, you must take care not to make global changes, e.g. to the built-in namespace. You should not use the GNU **gettext** API but instead the class-based API.

Let's say your module is called "spam" and the module's various natural language translation `.mo` files reside in `/usr/share/locale` in GNU **gettext** format. Here's what you would put at the top of your module:

```
import gettext
t = gettext.translation('spam', '/usr/share/locale')
_ = t.lgettext
```

If your translators were providing you with Unicode strings in their `.po` files, you'd instead do:

```
import gettext
t = gettext.translation('spam', '/usr/share/locale')
_ = t.ugettext
```

<sup>3</sup> François Pinard has written a program called **xpot** which does a similar job. It is available as part of his `po-utils` package.

<sup>4</sup> **msgfmt.py** is binary compatible with GNU **msgfmt** except that it provides a simpler, all-Python implementation. With this and **pygettext.py**, you generally won't need to install the GNU **gettext** package to internationalize your Python applications.

### Localizing your application

If you are localizing your application, you can install the `_()` function globally into the built-in namespace, usually in the main driver file of your application. This will let all your application-specific files just use `_( '. . . ' )` without having to explicitly install it in each file.

In the simple case then, you need only add the following bit of code to the main driver file of your application:

```
import gettext
gettext.install('myapplication')
```

If you need to set the locale directory or the `unicode` flag, you can pass these into the `install()` function:

```
import gettext
gettext.install('myapplication', '/usr/share/locale', unicode=1)
```

### Changing languages on the fly

If your program needs to support many languages at the same time, you may want to create multiple translation instances and then switch between them explicitly, like so:

```
import gettext

lang1 = gettext.translation('myapplication', languages=['en'])
lang2 = gettext.translation('myapplication', languages=['fr'])
lang3 = gettext.translation('myapplication', languages=['de'])

# start by using language 1
lang1.install()

# ... time goes by, user selects language 2
lang2.install()

# ... more time goes by, user selects language 3
lang3.install()
```

### Deferred translations

In most coding situations, strings are translated where they are coded. Occasionally however, you need to mark strings for translation, but defer actual translation until later. A classic example is:

```
animals = ['mollusk',
           'albatross',
           'rat',
           'penguin',
           'python', ]

# ...
for a in animals:
    print a
```

Here, you want to mark the strings in the `animals` list as being translatable, but you don't actually want to translate them until they are printed.

Here is one way you can handle this situation:

```
def _(message): return message
```

```
animals = [_('mollusk'),
           _('albatross'),
           _('rat'),
           _('penguin'),
           _('python'), ]
```

```
del _
```

```
# ...
for a in animals:
    print _(a)
```

This works because the dummy definition of `_( )` simply returns the string unchanged. And this dummy definition will temporarily override any definition of `_( )` in the built-in namespace (until the `del` command). Take care, though if you have a previous definition of `_( )` in the local namespace.

Note that the second use of `_( )` will not identify “a” as being translatable to the **pygettext** program, since it is not a string.

Another way to handle this is with the following example:

```
def N_(message): return message
```

```
animals = [N_('mollusk'),
           N_('albatross'),
           N_('rat'),
           N_('penguin'),
           N_('python'), ]
```

```
# ...
for a in animals:
    print _(a)
```

In this case, you are marking translatable strings with the function `N_( )`,<sup>5</sup> which won’t conflict with any definition of `_( )`. However, you will need to teach your message extraction program to look for translatable strings marked with `N_( )`. **pygettext** and **xpot** both support this through the use of command line switches.

### gettext ( ) vs. lgettext ( )

In Python 2.4 the `lgettext ( )` family of functions were introduced. The intention of these functions is to provide an alternative which is more compliant with the current implementation of GNU `gettext`. Unlike `gettext ( )`, which returns strings encoded with the same codeset used in the translation file, `lgettext ( )` will return strings encoded with the preferred system encoding, as returned by `locale.getpreferredencoding ( )`. Also notice that Python 2.4 introduces new functions to explicitly choose the codeset used in translated strings. If a codeset is explicitly set, even `lgettext ( )` will return translated strings in the requested codeset, as would be expected in the GNU `gettext` implementation.

## 22.1.4 Acknowledgements

The following people contributed code, feedback, design suggestions, previous implementations, and valuable experience to the creation of this module:

- Peter Funk

<sup>5</sup> The choice of `N_( )` here is totally arbitrary; it could have just as easily been `MarkThisStringForTranslation ( )`.

- James Henstridge
- Juan David Ibáñez Palomar
- Marc-André Lemburg
- Martin von Löwis
- François Pinard
- Barry Warsaw
- Gustavo Niemeyer

## 22.2 `locale` — Internationalization services

The `locale` module opens access to the POSIX locale database and functionality. The POSIX locale mechanism allows programmers to deal with certain cultural issues in an application, without requiring the programmer to know all the specifics of each country where the software is executed.

The `locale` module is implemented on top of the `_locale` module, which in turn uses an ANSI C locale implementation if available.

The `locale` module defines the following exception and functions:

### exception `locale.Error`

Exception raised when the locale passed to `setlocale()` is not recognized.

`locale.setlocale(category[, locale])`

If `locale` is given and not `None`, `setlocale()` modifies the locale setting for the `category`. The available categories are listed in the data description below. `locale` may be a string, or an iterable of two strings (language code and encoding). If it's an iterable, it's converted to a locale name using the locale aliasing engine. An empty string specifies the user's default settings. If the modification of the locale fails, the exception `Error` is raised. If successful, the new locale setting is returned.

If `locale` is omitted or `None`, the current setting for `category` is returned.

`setlocale()` is not thread-safe on most systems. Applications typically start with a call of

```
import locale
locale.setlocale(locale.LC_ALL, '')
```

This sets the locale for all categories to the user's default setting (typically specified in the `LANG` environment variable). If the locale is not changed thereafter, using multithreading should not cause problems. Changed in version 2.0: Added support for iterable values of the `locale` parameter.

`locale.localeconv()`

Returns the database of the local conventions as a dictionary. This dictionary has the following strings as keys:

Category	Key	Meaning
LC_NUMERIC	'decimal_point'	Decimal point character.
	'grouping'	Sequence of numbers specifying which relative positions the 'thousands_sep' is expected. If the sequence is terminated with CHAR_MAX, no further grouping is performed. If the sequence terminates with a 0, the last group size is repeatedly used.
LC_MONETARY	'thousands_sep'	Character used between groups.
	'int_curr_symbol'	International currency symbol.
	'currency_symbol'	Local currency symbol.
	'p_cs_precedes/n'	Whether the currency symbol precedes the value (for positive resp. negative values).
	'p_sep_by_space'	Whether the currency symbol is separated from the value by a space (for positive resp. negative values).
	'mon_decimal_point'	Decimal point used for monetary values.
	'frac_digits'	Number of fractional digits used in local formatting of monetary values.
	'int_frac_digits'	Number of fractional digits used in international formatting of monetary values.
	'mon_thousands_sep'	Group separator used for monetary values.
	'mon_grouping'	Equivalent to 'grouping', used for monetary values.
	'positive_sign'	Symbol used to annotate a positive monetary value.
'negative_sign'	Symbol used to annotate a negative monetary value.	
'p_sign_posn/n'	The position of the sign (for positive resp. negative values), see below.	

All numeric values can be set to CHAR\_MAX to indicate that there is no value specified in this locale.

The possible values for 'p\_sign\_posn' and 'n\_sign\_posn' are given below.

Value	Explanation
0	Currency and value are surrounded by parentheses.
1	The sign should precede the value and currency symbol.
2	The sign should follow the value and currency symbol.
3	The sign should immediately precede the value.
4	The sign should immediately follow the value.
CHAR_MAX	Nothing is specified in this locale.

`locale.nl_langinfo(option)`

Return some locale-specific information as a string. This function is not available on all systems, and the set of possible options might also vary across platforms. The possible argument values are numbers, for which symbolic constants are available in the locale module.

The `nl_langinfo()` function accepts one of the following keys. Most descriptions are taken from the corresponding description in the GNU C library.

`locale.CODESET`

Get a string with the name of the character encoding used in the selected locale.

`locale.D_T_FMT`

Get a string that can be used as a format string for `time.strftime()` to represent date and time in a locale-specific way.

`locale.D_FMT`

Get a string that can be used as a format string for `time.strftime()` to represent a date in a locale-specific way.

`locale.T_FMT`

Get a string that can be used as a format string for `time.strftime()` to represent a time in a locale-specific way.

`locale.T_FMT_AMPM`

Get a format string for `time.strftime()` to represent time in the am/pm format.

`DAY_1 ... DAY_7`

Get the name of the n-th day of the week.

---

**Note:** This follows the US convention of `DAY_1` being Sunday, not the international convention (ISO 8601) that Monday is the first day of the week.

---

`ABDAY_1 ... ABDAY_7`

Get the abbreviated name of the n-th day of the week.

`MON_1 ... MON_12`

Get the name of the n-th month.

`ABMON_1 ... ABMON_12`

Get the abbreviated name of the n-th month.

`locale.RADIXCHAR`

Get the radix character (decimal dot, decimal comma, etc.)

`locale.THOUSEP`

Get the separator character for thousands (groups of three digits).

`locale.YESEXPR`

Get a regular expression that can be used with the `regex` function to recognize a positive response to a yes/no question.

---

**Note:** The expression is in the syntax suitable for the `regex()` function from the C library, which might differ from the syntax used in `re`.

---

`locale.NOEXPR`

Get a regular expression that can be used with the `regex(3)` function to recognize a negative response to a yes/no question.

`locale.CRNCYSTR`

Get the currency symbol, preceded by “-” if the symbol should appear before the value, “+” if the symbol should appear after the value, or “.” if the symbol should replace the radix character.

`locale.ERA`

Get a string that represents the era used in the current locale.

Most locales do not define this value. An example of a locale which does define this value is the Japanese one. In Japan, the traditional representation of dates includes the name of the era corresponding to the then-emperor’s reign.

Normally it should not be necessary to use this value directly. Specifying the `E` modifier in their format strings causes the `time.strftime()` function to use this information. The format of the returned string is not specified, and therefore you should not assume knowledge of it on different systems.

`locale.ERA_D_T_FMT`

Get a format string for `time.strftime()` to represent date and time in a locale-specific era-based way.

`locale.ERA_D_FMT`

Get a format string for `time.strftime()` to represent a date in a locale-specific era-based way.

`locale.ERA_T_FMT`

Get a format string for `time.strftime()` to represent a time in a locale-specific era-based way.

`locale.ALT_DIGITS`

Get a representation of up to 100 values used to represent the values 0 to 99.

`locale.getdefaultlocale([envvars])`

Tries to determine the default locale settings and returns them as a tuple of the form (language code, encoding).

According to POSIX, a program which has not called `setlocale(LC_ALL, "")` runs using the portable 'C' locale. Calling `setlocale(LC_ALL, "")` lets it use the default locale as defined by the `LANG` variable. Since we do not want to interfere with the current locale setting we thus emulate the behavior in the way described above.

To maintain compatibility with other platforms, not only the `LANG` variable is tested, but a list of variables given as `envvars` parameter. The first found to be defined will be used. `envvars` defaults to the search path used in GNU `gettext`; it must always contain the variable name `LANG`. The GNU `gettext` search path contains 'LANGUAGE', 'LC\_ALL', 'LC\_CTYPE', and 'LANG', in that order.

Except for the code 'C', the language code corresponds to [RFC 1766](#). *language code* and *encoding* may be `None` if their values cannot be determined. New in version 2.0.

`locale.getlocale([category])`

Returns the current setting for the given locale category as sequence containing *language code*, *encoding*. *category* may be one of the `LC_*` values except `LC_ALL`. It defaults to `LC_CTYPE`.

Except for the code 'C', the language code corresponds to [RFC 1766](#). *language code* and *encoding* may be `None` if their values cannot be determined. New in version 2.0.

`locale.getpreferredencoding([do_setlocale])`

Return the encoding used for text data, according to user preferences. User preferences are expressed differently on different systems, and might not be available programmatically on some systems, so this function only returns a guess.

On some systems, it is necessary to invoke `setlocale()` to obtain the user preferences, so this function is not thread-safe. If invoking `setlocale` is not necessary or desired, `do_setlocale` should be set to `False`. New in version 2.3.

`locale.normalize(localename)`

Returns a normalized locale code for the given locale name. The returned locale code is formatted for use with `setlocale()`. If normalization fails, the original name is returned unchanged.

If the given encoding is not known, the function defaults to the default encoding for the locale code just like `setlocale()`. New in version 2.0.

`locale.resetlocale([category])`

Sets the locale for *category* to the default setting.

The default setting is determined by calling `getdefaultlocale()`. *category* defaults to `LC_ALL`. New in version 2.0.

`locale.strcoll(string1, string2)`

Compares two strings according to the current `LC_COLLATE` setting. As any other compare function, returns a negative, or a positive value, or 0, depending on whether *string1* collates before or after *string2* or is equal to it.

`locale.strxfrm(string)`

Transforms a string to one that can be used for the built-in function `cmp()`, and still returns locale-aware results. This function can be used when the same string is compared repeatedly, e.g. when collating a sequence of strings.

`locale.format(format, val[, grouping[, monetary]])`

Formats a number *val* according to the current `LC_NUMERIC` setting. The format follows the conventions of

the `%` operator. For floating point values, the decimal point is modified if appropriate. If *grouping* is true, also takes the grouping into account.

If *monetary* is true, the conversion uses monetary thousands separator and grouping strings.

Please note that this function will only work for exactly one *%char* specifier. For whole format strings, use `format_string()`. Changed in version 2.5: Added the *monetary* parameter.

`locale.format_string(format, val[, grouping])`

Processes formatting specifiers as in `format % val`, but takes the current locale settings into account. New in version 2.5.

`locale.currency(val[, symbol[, grouping[, international]]])`

Formats a number *val* according to the current `LC_MONETARY` settings.

The returned string includes the currency symbol if *symbol* is true, which is the default. If *grouping* is true (which is not the default), grouping is done with the value. If *international* is true (which is not the default), the international currency symbol is used.

Note that this function will not work with the 'C' locale, so you have to set a locale via `setlocale()` first. New in version 2.5.

`locale.str(float)`

Formats a floating point number using the same format as the built-in function `str(float)`, but takes the decimal point into account.

`locale.atof(string)`

Converts a string to a floating point number, following the `LC_NUMERIC` settings.

`locale.atoi(string)`

Converts a string to an integer, following the `LC_NUMERIC` conventions.

`locale.LC_CTYPE`

Locale category for the character type functions. Depending on the settings of this category, the functions of module `string` dealing with case change their behaviour.

`locale.LC_COLLATE`

Locale category for sorting strings. The functions `strcoll()` and `strxfrm()` of the `locale` module are affected.

`locale.LC_TIME`

Locale category for the formatting of time. The function `time.strftime()` follows these conventions.

`locale.LC_MONETARY`

Locale category for formatting of monetary values. The available options are available from the `localeconv()` function.

`locale.LC_MESSAGES`

Locale category for message display. Python currently does not support application specific locale-aware messages. Messages displayed by the operating system, like those returned by `os.strerror()` might be affected by this category.

`locale.LC_NUMERIC`

Locale category for formatting numbers. The functions `format()`, `atoi()`, `atof()` and `str()` of the `locale` module are affected by that category. All other numeric formatting operations are not affected.

`locale.LC_ALL`

Combination of all locale settings. If this flag is used when the locale is changed, setting the locale for all categories is attempted. If that fails for any category, no category is changed at all. When the locale is retrieved using this flag, a string indicating the setting for all categories is returned. This string can be later used to restore the settings.

`locale.CHAR_MAX`

This is a symbolic constant used for different values returned by `localeconv()`.

Example:

```
>>> import locale
>>> loc = locale.getlocale() # get current locale
# use German locale; name might vary with platform
>>> locale.setlocale(locale.LC_ALL, 'de_DE')
>>> locale.strcoll('f\xfe4n', 'foo') # compare a string containing an umlaut
>>> locale.setlocale(locale.LC_ALL, '') # use user's preferred locale
>>> locale.setlocale(locale.LC_ALL, 'C') # use default (C) locale
>>> locale.setlocale(locale.LC_ALL, loc) # restore saved locale
```

## 22.2.1 Background, details, hints, tips and caveats

The C standard defines the locale as a program-wide property that may be relatively expensive to change. On top of that, some implementation are broken in such a way that frequent locale changes may cause core dumps. This makes the locale somewhat painful to use correctly.

Initially, when a program is started, the locale is the C locale, no matter what the user's preferred locale is. The program must explicitly say that it wants the user's preferred locale settings by calling `setlocale(LC_ALL, "")`.

It is generally a bad idea to call `setlocale()` in some library routine, since as a side effect it affects the entire program. Saving and restoring it is almost as bad: it is expensive and affects other threads that happen to run before the settings have been restored.

If, when coding a module for general use, you need a locale independent version of an operation that is affected by the locale (such as `string.lower()`, or certain formats used with `time.strftime()`), you will have to find a way to do it without using the standard library routine. Even better is convincing yourself that using locale settings is okay. Only as a last resort should you document that your module is not compatible with non-C locale settings.

The case conversion functions in the `string` module are affected by the locale settings. When a call to the `setlocale()` function changes the `LC_CTYPE` settings, the variables `string.lowercase`, `string.uppercase` and `string.letters` are recalculated. Note that code that uses these variable through 'from ... import ...', e.g. `from string import letters`, is not affected by subsequent `setlocale()` calls.

The only way to perform numeric operations according to the locale is to use the special functions defined by this module: `atof()`, `atoi()`, `format()`, `str()`.

## 22.2.2 For extension writers and programs that embed Python

Extension modules should never call `setlocale()`, except to find out what the current locale is. But since the return value can only be used portably to restore it, that is not very useful (except perhaps to find out whether or not the locale is C).

When Python code uses the `locale` module to change the locale, this also affects the embedding application. If the embedding application doesn't want this to happen, it should remove the `_locale` extension module (which does all the work) from the table of built-in modules in the `config.c` file, and make sure that the `_locale` module is not accessible as a shared library.

### 22.2.3 Access to message catalogs

The `locale` module exposes the C library's `gettext` interface on systems that provide this interface. It consists of the functions `gettext()`, `dgettext()`, `dcgettext()`, `textdomain()`, `bindtextdomain()`, and `bind_textdomain_codeset()`. These are similar to the same functions in the `gettext` module, but use the C library's binary format for message catalogs, and the C library's search algorithms for locating message catalogs.

Python applications should normally find no need to invoke these functions, and should use `gettext` instead. A known exception to this rule are applications that link with additional C libraries which internally invoke `gettext()` or `dcgettext()`. For these applications, it may be necessary to bind the text domain, so that the libraries can properly locate their message catalogs.

# PROGRAM FRAMEWORKS

The modules described in this chapter are frameworks that will largely dictate the structure of your program. Currently the modules described here are all oriented toward writing command-line interfaces.

The full list of modules described in this chapter is:

## 23.1 `cmd` — Support for line-oriented command interpreters

Source code: [Lib/cmd.py](#)

---

The `Cmd` class provides a simple framework for writing line-oriented command interpreters. These are often useful for test harnesses, administrative tools, and prototypes that will later be wrapped in a more sophisticated interface.

**class** `cmd.Cmd` (`[completekey[, stdin[, stdout]]`)

A `Cmd` instance or subclass instance is a line-oriented interpreter framework. There is no good reason to instantiate `Cmd` itself; rather, it's useful as a superclass of an interpreter class you define yourself in order to inherit `Cmd`'s methods and encapsulate action methods.

The optional argument `completekey` is the `readline` name of a completion key; it defaults to `Tab`. If `completekey` is not `None` and `readline` is available, command completion is done automatically.

The optional arguments `stdin` and `stdout` specify the input and output file objects that the `Cmd` instance or subclass instance will use for input and output. If not specified, they will default to `sys.stdin` and `sys.stdout`.

If you want a given `stdin` to be used, make sure to set the instance's `use_rawinput` attribute to `False`, otherwise `stdin` will be ignored. Changed in version 2.3: The `stdin` and `stdout` parameters were added.

### 23.1.1 `Cmd` Objects

A `Cmd` instance has the following methods:

`Cmd.cmdloop` (`[intro]`)

Repeatedly issue a prompt, accept input, parse an initial prefix off the received input, and dispatch to action methods, passing them the remainder of the line as argument.

The optional argument is a banner or intro string to be issued before the first prompt (this overrides the `intro` class attribute).

If the `readline` module is loaded, input will automatically inherit **bash**-like history-list editing (e.g. `Control-P` scrolls back to the last command, `Control-N` forward to the next one, `Control-F` moves the cursor to the right non-destructively, `Control-B` moves the cursor to the left non-destructively, etc.).

An end-of-file on input is passed back as the string 'EOF'.

An interpreter instance will recognize a command name `foo` if and only if it has a method `do_foo()`. As a special case, a line beginning with the character '?' is dispatched to the method `do_help()`. As another special case, a line beginning with the character '!' is dispatched to the method `do_shell()` (if such a method is defined).

This method will return when the `postcmd()` method returns a true value. The `stop` argument to `postcmd()` is the return value from the command's corresponding `do_*()` method.

If completion is enabled, completing commands will be done automatically, and completing of commands args is done by calling `complete_foo()` with arguments `text`, `line`, `begidx`, and `endidx`. `text` is the string prefix we are attempting to match: all returned matches must begin with it. `line` is the current input line with leading whitespace removed, `begidx` and `endidx` are the beginning and ending indexes of the prefix text, which could be used to provide different completion depending upon which position the argument is in.

All subclasses of `Cmd` inherit a predefined `do_help()`. This method, called with an argument 'bar', invokes the corresponding method `help_bar()`, and if that is not present, prints the docstring of `do_bar()`, if available. With no argument, `do_help()` lists all available help topics (that is, all commands with corresponding `help_*()` methods or commands that have docstrings), and also lists any undocumented commands.

**Cmd.onecmd** (*str*)

Interpret the argument as though it had been typed in response to the prompt. This may be overridden, but should not normally need to be; see the `precmd()` and `postcmd()` methods for useful execution hooks. The return value is a flag indicating whether interpretation of commands by the interpreter should stop. If there is a `do_*()` method for the command *str*, the return value of that method is returned, otherwise the return value from the `default()` method is returned.

**Cmd.emptyline** ()

Method called when an empty line is entered in response to the prompt. If this method is not overridden, it repeats the last nonempty command entered.

**Cmd.default** (*line*)

Method called on an input line when the command prefix is not recognized. If this method is not overridden, it prints an error message and returns.

**Cmd.completedefault** (*text*, *line*, *begidx*, *endidx*)

Method called to complete an input line when no command-specific `complete_*()` method is available. By default, it returns an empty list.

**Cmd.precmd** (*line*)

Hook method executed just before the command line *line* is interpreted, but after the input prompt is generated and issued. This method is a stub in `Cmd`; it exists to be overridden by subclasses. The return value is used as the command which will be executed by the `onecmd()` method; the `precmd()` implementation may re-write the command or simply return *line* unchanged.

**Cmd.postcmd** (*stop*, *line*)

Hook method executed just after a command dispatch is finished. This method is a stub in `Cmd`; it exists to be overridden by subclasses. *line* is the command line which was executed, and *stop* is a flag which indicates whether execution will be terminated after the call to `postcmd()`; this will be the return value of the `onecmd()` method. The return value of this method will be used as the new value for the internal flag which corresponds to *stop*; returning false will cause interpretation to continue.

**Cmd.preloop** ()

Hook method executed once when `cmdloop()` is called. This method is a stub in `Cmd`; it exists to be overridden by subclasses.

**Cmd.postloop** ()

Hook method executed once when `cmdloop()` is about to return. This method is a stub in `Cmd`; it exists to be overridden by subclasses.

Instances of `Cmd` subclasses have some public instance variables:

`Cmd.prompt`

The prompt issued to solicit input.

`Cmd.identchars`

The string of characters accepted for the command prefix.

`Cmd.lastcmd`

The last nonempty command prefix seen.

`Cmd.intro`

A string to issue as an intro or banner. May be overridden by giving the `cmdloop()` method an argument.

`Cmd.doc_header`

The header to issue if the help output has a section for documented commands.

`Cmd.misc_header`

The header to issue if the help output has a section for miscellaneous help topics (that is, there are `help_*()` methods without corresponding `do_*()` methods).

`Cmd.undoc_header`

The header to issue if the help output has a section for undocumented commands (that is, there are `do_*()` methods without corresponding `help_*()` methods).

`Cmd.ruler`

The character used to draw separator lines under the help-message headers. If empty, no ruler line is drawn. It defaults to `'='`.

`Cmd.use_rawinput`

A flag, defaulting to true. If true, `cmdloop()` uses `raw_input()` to display a prompt and read the next command; if false, `sys.stdout.write()` and `sys.stdin.readline()` are used. (This means that by importing `readline`, on systems that support it, the interpreter will automatically support **Emacs**-like line editing and command-history keystrokes.)

## 23.2 shlex — Simple lexical analysis

New in version 1.5.2. **Source code:** [Lib/shlex.py](#)

The `shlex` class makes it easy to write lexical analyzers for simple syntaxes resembling that of the Unix shell. This will often be useful for writing minilanguages, (for example, in run control files for Python applications) or for parsing quoted strings.

Prior to Python 2.7.3, this module did not support Unicode input.

The `shlex` module defines the following functions:

`shlex.split(s[, comments[, posix]])`

Split the string `s` using shell-like syntax. If `comments` is `False` (the default), the parsing of comments in the given string will be disabled (setting the `commenters` attribute of the `shlex` instance to the empty string). This function operates in POSIX mode by default, but uses non-POSIX mode if the `posix` argument is false. New in version 2.3.Changed in version 2.6: Added the `posix` parameter.

**Note:** Since the `split()` function instantiates a `shlex` instance, passing `None` for `s` will read the string to split from standard input.

The `shlex` module defines the following class:

**class** `shlex.shlex` (`[instream`, `[infile`, `posix]` ] ] )

A `shlex` instance or subclass instance is a lexical analyzer object. The initialization argument, if present, specifies where to read characters from. It must be a file-/stream-like object with `read()` and `readline()` methods, or a string (strings are accepted since Python 2.3). If no argument is given, input will be taken from `sys.stdin`. The second optional argument is a filename string, which sets the initial value of the `infile` attribute. If the `instream` argument is omitted or equal to `sys.stdin`, this second argument defaults to “stdin”. The `posix` argument was introduced in Python 2.3, and defines the operational mode. When `posix` is not true (default), the `shlex` instance will operate in compatibility mode. When operating in POSIX mode, `shlex` will try to be as close as possible to the POSIX shell parsing rules.

**See Also:**

**Module** `ConfigParser` Parser for configuration files similar to the Windows `.ini` files.

## 23.2.1 shlex Objects

A `shlex` instance has the following methods:

`shlex.get_token()`

Return a token. If tokens have been stacked using `push_token()`, pop a token off the stack. Otherwise, read one from the input stream. If reading encounters an immediate end-of-file, `self.eof` is returned (the empty string (“”) in non-POSIX mode, and `None` in POSIX mode).

`shlex.push_token(str)`

Push the argument onto the token stack.

`shlex.read_token()`

Read a raw token. Ignore the pushback stack, and do not interpret source requests. (This is not ordinarily a useful entry point, and is documented here only for the sake of completeness.)

`shlex.sourcehook(filename)`

When `shlex` detects a source request (see `source` below) this method is given the following token as argument, and expected to return a tuple consisting of a filename and an open file-like object.

Normally, this method first strips any quotes off the argument. If the result is an absolute pathname, or there was no previous source request in effect, or the previous source was a stream (such as `sys.stdin`), the result is left alone. Otherwise, if the result is a relative pathname, the directory part of the name of the file immediately before it on the source inclusion stack is prepended (this behavior is like the way the C preprocessor handles `#include "file.h"`).

The result of the manipulations is treated as a filename, and returned as the first component of the tuple, with `open()` called on it to yield the second component. (Note: this is the reverse of the order of arguments in instance initialization!)

This hook is exposed so that you can use it to implement directory search paths, addition of file extensions, and other namespace hacks. There is no corresponding ‘close’ hook, but a `shlex` instance will call the `close()` method of the sourced input stream when it returns EOF.

For more explicit control of source stacking, use the `push_source()` and `pop_source()` methods.

`shlex.push_source(stream`, `[filename]` )

Push an input source stream onto the input stack. If the filename argument is specified it will later be available for use in error messages. This is the same method used internally by the `sourcehook()` method. New in version 2.1.

`shlex.pop_source()`

Pop the last-pushed input source from the input stack. This is the same method used internally when the lexer reaches EOF on a stacked input stream. New in version 2.1.

`shlex.error_leader([file[, line]])`

This method generates an error message leader in the format of a Unix C compiler error label; the format is `'%s', line %d: '`, where the `%s` is replaced with the name of the current source file and the `%d` with the current input line number (the optional arguments can be used to override these).

This convenience is provided to encourage `shlex` users to generate error messages in the standard, parseable format understood by Emacs and other Unix tools.

Instances of `shlex` subclasses have some public instance variables which either control lexical analysis or can be used for debugging:

`shlex.commenters`

The string of characters that are recognized as comment beginners. All characters from the comment beginner to end of line are ignored. Includes just `'#'` by default.

`shlex.wordchars`

The string of characters that will accumulate into multi-character tokens. By default, includes all ASCII alphanumeric characters and underscore.

`shlex.whitespace`

Characters that will be considered whitespace and skipped. Whitespace bounds tokens. By default, includes space, tab, linefeed and carriage-return.

`shlex.escape`

Characters that will be considered as escape. This will be only used in POSIX mode, and includes just `'\'` by default. New in version 2.3.

`shlex.quotes`

Characters that will be considered string quotes. The token accumulates until the same quote is encountered again (thus, different quote types protect each other as in the shell.) By default, includes ASCII single and double quotes.

`shlex.escapedquotes`

Characters in `quotes` that will interpret escape characters defined in `escape`. This is only used in POSIX mode, and includes just `'\"'` by default. New in version 2.3.

`shlex.whitespace_split`

If `True`, tokens will only be split in whitespaces. This is useful, for example, for parsing command lines with `shlex`, getting tokens in a similar way to shell arguments. New in version 2.3.

`shlex.infile`

The name of the current input file, as initially set at class instantiation time or stacked by later source requests. It may be useful to examine this when constructing error messages.

`shlex.instream`

The input stream from which this `shlex` instance is reading characters.

`shlex.source`

This attribute is `None` by default. If you assign a string to it, that string will be recognized as a lexical-level inclusion request similar to the `source` keyword in various shells. That is, the immediately following token will be opened as a filename and input taken from that stream until EOF, at which point the `close()` method of that stream will be called and the input source will again become the original input stream. Source requests may be stacked any number of levels deep.

`shlex.debug`

If this attribute is numeric and 1 or more, a `shlex` instance will print verbose progress output on its behavior. If you need to use this, you can read the module source code to learn the details.

`shlex.lineno`

Source line number (count of newlines seen so far plus one).

### `shlex.token`

The token buffer. It may be useful to examine this when catching exceptions.

### `shlex.eof`

Token used to determine end of file. This will be set to the empty string (`""`), in non-POSIX mode, and to `None` in POSIX mode. New in version 2.3.

## 23.2.2 Parsing Rules

When operating in non-POSIX mode, `shlex` will try to obey to the following rules.

- Quote characters are not recognized within words (`Do"Not"Separate` is parsed as the single word `Do"Not"Separate`);
- Escape characters are not recognized;
- Enclosing characters in quotes preserve the literal value of all characters within the quotes;
- Closing quotes separate words (`"Do"Separate` is parsed as `"Do"` and `Separate`);
- If `whitespace_split` is `False`, any character not declared to be a word character, whitespace, or a quote will be returned as a single-character token. If it is `True`, `shlex` will only split words in whitespaces;
- EOF is signaled with an empty string (`""`);
- It's not possible to parse empty strings, even if quoted.

When operating in POSIX mode, `shlex` will try to obey to the following parsing rules.

- Quotes are stripped out, and do not separate words (`"Do"Not"Separate"` is parsed as the single word `DoNotSeparate`);
- Non-quoted escape characters (e.g. `'\'`) preserve the literal value of the next character that follows;
- Enclosing characters in quotes which are not part of `escapedquotes` (e.g. `"' "`) preserve the literal value of all characters within the quotes;
- Enclosing characters in quotes which are part of `escapedquotes` (e.g. `'"'`) preserves the literal value of all characters within the quotes, with the exception of the characters mentioned in `escape`. The escape characters retain its special meaning only when followed by the quote in use, or the escape character itself. Otherwise the escape character will be considered a normal character.
- EOF is signaled with a `None` value;
- Quoted empty strings (`""`) are allowed;

# GRAPHICAL USER INTERFACES WITH TK

Tk/Tcl has long been an integral part of Python. It provides a robust and platform independent windowing toolkit, that is available to Python programmers using the `Tkinter` module, and its extensions, the `Tix` and the `ttk` modules.

The `Tkinter` module is a thin object-oriented layer on top of Tcl/Tk. To use `Tkinter`, you don't need to write Tcl code, but you will need to consult the Tk documentation, and occasionally the Tcl documentation. `Tkinter` is a set of wrappers that implement the Tk widgets as Python classes. In addition, the internal module `_tkinter` provides a threadsafe mechanism which allows Python and Tcl to interact.

`Tkinter`'s chief virtues are that it is fast, and that it usually comes bundled with Python. Although its standard documentation is weak, good material is available, which includes: references, tutorials, a book and others. `Tkinter` is also famous for having an outdated look and feel, which has been vastly improved in Tk 8.5. Nevertheless, there are many other GUI libraries that you could be interested in. For more information about alternatives, see the *Other Graphical User Interface Packages* section.

## 24.1 Tkinter — Python interface to Tcl/Tk

The `Tkinter` module (“Tk interface”) is the standard Python interface to the Tk GUI toolkit. Both Tk and `Tkinter` are available on most Unix platforms, as well as on Windows systems. (Tk itself is not part of Python; it is maintained at ActiveState.)

---

**Note:** `Tkinter` has been renamed to `tkinter` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

### See Also:

**Python Tkinter Resources** The Python Tkinter Topic Guide provides a great deal of information on using Tk from Python and links to other sources of information on Tk.

**TKDocs** Extensive tutorial plus friendlier widget pages for some of the widgets.

**Tkinter reference: a GUI for Python** On-line reference material.

**Tkinter docs from effbot** Online reference for tkinter supported by effbot.org.

**Tcl/Tk manual** Official manual for the latest tcl/tk version.

**Programming Python** Book by Mark Lutz, has excellent coverage of Tkinter.

**Modern Tkinter for Busy Python Developers** Book by Mark Rozerman about building attractive and modern graphical user interfaces with Python and Tkinter.

**An Introduction to Tkinter** Fredrik Lundh's on-line reference material.

**Python and Tkinter Programming** The book by John Grayson (ISBN 1-884777-81-3).

### 24.1.1 Tkinter Modules

Most of the time, the `Tkinter` module is all you really need, but a number of additional modules are available as well. The Tk interface is located in a binary module named `_tkinter`. This module contains the low-level interface to Tk, and should never be used directly by application programmers. It is usually a shared library (or DLL), but might in some cases be statically linked with the Python interpreter.

In addition to the Tk interface module, `Tkinter` includes a number of Python modules. The two most important modules are the `Tkinter` module itself, and a module called `Tkconstants`. The former automatically imports the latter, so to use Tkinter, all you need to do is to import one module:

```
import Tkinter
```

Or, more often:

```
from Tkinter import *
```

```
class Tkinter.Tk (screenName=None, baseName=None, className='Tk', useTk=1)
```

The `Tk` class is instantiated without arguments. This creates a toplevel widget of Tk which usually is the main window of an application. Each instance has its own associated Tcl interpreter. Changed in version 2.4: The `useTk` parameter was added.

```
Tkinter.Tcl (screenName=None, baseName=None, className='Tk', useTk=0)
```

The `Tcl()` function is a factory function which creates an object much like that created by the `Tk` class, except that it does not initialize the Tk subsystem. This is most often useful when driving the Tcl interpreter in an environment where one doesn't want to create extraneous toplevel windows, or where one cannot (such as Unix/Linux systems without an X server). An object created by the `Tcl()` object can have a Toplevel window created (and the Tk subsystem initialized) by calling its `loadtk()` method. New in version 2.4.

Other modules that provide Tk support include:

**ScrolledText** Text widget with a vertical scroll bar built in.

**tkColorChooser** Dialog to let the user choose a color.

**tkCommonDialog** Base class for the dialogs defined in the other modules listed here.

**tkFileDialog** Common dialogs to allow the user to specify a file to open or save.

**tkFont** Utilities to help work with fonts.

**tkMessageBox** Access to standard Tk dialog boxes.

**tkSimpleDialog** Basic dialogs and convenience functions.

**Tkdnd** Drag-and-drop support for `Tkinter`. This is experimental and should become deprecated when it is replaced with the Tk DND.

**turtle** Turtle graphics in a Tk window.

These have been renamed as well in Python 3; they were all made submodules of the new `tkinter` package.

### 24.1.2 Tkinter Life Preserver

This section is not designed to be an exhaustive tutorial on either Tk or Tkinter. Rather, it is intended as a stop gap, providing some introductory orientation on the system.

Credits:

- Tkinter was written by Steen Lumholt and Guido van Rossum.
- Tk was written by John Ousterhout while at Berkeley.
- This Life Preserver was written by Matt Conway at the University of Virginia.
- The html rendering, and some liberal editing, was produced from a FrameMaker version by Ken Manheimer.
- Fredrik Lundh elaborated and revised the class interface descriptions, to get them current with Tk 4.2.
- Mike Clarkson converted the documentation to LaTeX, and compiled the User Interface chapter of the reference manual.

## How To Use This Section

This section is designed in two parts: the first half (roughly) covers background material, while the second half can be taken to the keyboard as a handy reference.

When trying to answer questions of the form “how do I do blah”, it is often best to find out how to do “blah” in straight Tk, and then convert this back into the corresponding `Tkinter` call. Python programmers can often guess at the correct Python command by looking at the Tk documentation. This means that in order to use Tkinter, you will have to know a little bit about Tk. This document can’t fulfill that role, so the best we can do is point you to the best documentation that exists. Here are some hints:

- The authors strongly suggest getting a copy of the Tk man pages. Specifically, the man pages in the `man` directory are most useful. The `man3` man pages describe the C interface to the Tk library and thus are not especially helpful for script writers.
- Addison-Wesley publishes a book called *Tcl and the Tk Toolkit* by John Ousterhout (ISBN 0-201-63337-X) which is a good introduction to Tcl and Tk for the novice. The book is not exhaustive, and for many details it defers to the man pages.
- `Tkinter.py` is a last resort for most, but can be a good place to go when nothing else makes sense.

### See Also:

**ActiveState Tcl Home Page** The Tk/Tcl development is largely taking place at ActiveState.

**Tcl and the Tk Toolkit** The book by John Ousterhout, the inventor of Tcl.

**Practical Programming in Tcl and Tk** Brent Welch’s encyclopedic book.

## A Simple Hello World Program

```
from Tkinter import *

class Application(Frame):
    def say_hi(self):
        print "hi there, everyone!"

    def createWidgets(self):
        self.QUIT = Button(self)
        self.QUIT["text"] = "QUIT"
        self.QUIT["fg"] = "red"
        self.QUIT["command"] = self.quit

        self.QUIT.pack({"side": "left"})

        self.hi_there = Button(self)
```

```

self.hi_there["text"] = "Hello",
self.hi_there["command"] = self.say_hi

self.hi_there.pack({"side": "left"})

def __init__(self, master=None):
    Frame.__init__(self, master)
    self.pack()
    self.createWidgets()

root = Tk()
app = Application(master=root)
app.mainloop()
root.destroy()

```

### 24.1.3 A (Very) Quick Look at Tcl/Tk

The class hierarchy looks complicated, but in actual practice, application programmers almost always refer to the classes at the very bottom of the hierarchy.

Notes:

- These classes are provided for the purposes of organizing certain functions under one namespace. They aren't meant to be instantiated independently.
- The `Tk` class is meant to be instantiated only once in an application. Application programmers need not instantiate one explicitly, the system creates one whenever any of the other classes are instantiated.
- The `Widget` class is not meant to be instantiated, it is meant only for subclassing to make “real” widgets (in C++, this is called an ‘abstract class’).

To make use of this reference material, there will be times when you will need to know how to read short passages of Tk and how to identify the various parts of a Tk command. (See section *Mapping Basic Tk into Tkinter* for the `Tkinter` equivalents of what's below.)

Tk scripts are Tcl programs. Like all Tcl programs, Tk scripts are just lists of tokens separated by spaces. A Tk widget is just its *class*, the *options* that help configure it, and the *actions* that make it do useful things.

To make a widget in Tk, the command is always of the form:

```
classCommand newPathname options
```

**classCommand** denotes which kind of widget to make (a button, a label, a menu...)

**newPathname** is the new name for this widget. All names in Tk must be unique. To help enforce this, widgets in Tk are named with *pathnames*, just like files in a file system. The top level widget, the *root*, is called `.` (period) and children are delimited by more periods. For example, `.myApp.controlPanel.okButton` might be the name of a widget.

**options** configure the widget's appearance and in some cases, its behavior. The options come in the form of a list of flags and values. Flags are preceded by a '-', like Unix shell command flags, and values are put in quotes if they are more than one word.

For example:

```

button .fred -fg red -text "hi there"
  ^         ^         \_____/
  |         |         |
class  new      options
command widget (-opt val -opt val ...)

```

Once created, the pathname to the widget becomes a new command. This new *widget command* is the programmer's handle for getting the new widget to perform some *action*. In C, you'd express this as `someAction(fred, someOptions)`, in C++, you would express this as `fred.someAction(someOptions)`, and in Tk, you say:

```
.fred someAction someOptions
```

Note that the object name, `.fred`, starts with a dot.

As you'd expect, the legal values for *someAction* will depend on the widget's class: `.fred disable` works if `fred` is a button (fred gets greyed out), but does not work if `fred` is a label (disabling of labels is not supported in Tk).

The legal values of *someOptions* is action dependent. Some actions, like `disable`, require no arguments, others, like a text-entry box's `delete` command, would need arguments to specify what range of text to delete.

### 24.1.4 Mapping Basic Tk into Tkinter

Class commands in Tk correspond to class constructors in Tkinter.

```
button .fred                =====> fred = Button()
```

The master of an object is implicit in the new name given to it at creation time. In Tkinter, masters are specified explicitly.

```
button .panel.fred          =====> fred = Button(panel)
```

The configuration options in Tk are given in lists of hyphenated tags followed by values. In Tkinter, options are specified as keyword-arguments in the instance constructor, and keyword-args for `configure` calls or as instance indices, in dictionary style, for established instances. See section [Setting Options](#) on setting options.

```
button .fred -fg red        =====> fred = Button(panel, fg = "red")
.fred configure -fg red     =====> fred["fg"] = red
OR ==> fred.config(fg = "red")
```

In Tk, to perform an action on a widget, use the widget name as a command, and follow it with an action name, possibly with arguments (options). In Tkinter, you call methods on the class instance to invoke actions on the widget. The actions (methods) that a given widget can perform are listed in the `Tkinter.py` module.

```
.fred invoke                =====> fred.invoke()
```

To give a widget to the packer (geometry manager), you call `pack` with optional arguments. In Tkinter, the `Pack` class holds all this functionality, and the various forms of the `pack` command are implemented as methods. All widgets in `Tkinter` are subclassed from the `Packer`, and so inherit all the packing methods. See the `Tix` module documentation for additional information on the Form geometry manager.

```
pack .fred -side left       =====> fred.pack(side = "left")
```

### 24.1.5 How Tk and Tkinter are Related

From the top down:

**Your App Here (Python)** A Python application makes a `Tkinter` call.

**Tkinter (Python Module)** This call (say, for example, creating a button widget), is implemented in the `Tkinter` module, which is written in Python. This Python function will parse the commands and the arguments and convert them into a form that makes them look as if they had come from a Tk script instead of a Python script.

**tkinter (C)** These commands and their arguments will be passed to a C function in the `tkinter` - note the lowercase - extension module.

**Tk Widgets (C and Tcl)** This C function is able to make calls into other C modules, including the C functions that make up the Tk library. Tk is implemented in C and some Tcl. The Tcl part of the Tk widgets is used to bind certain default behaviors to widgets, and is executed once at the point where the Python `Tkinter` module is imported. (The user never sees this stage).

**Tk (C)** The Tk part of the Tk Widgets implement the final mapping to ...

**Xlib (C)** the Xlib library to draw graphics on the screen.

## 24.1.6 Handy Reference

### Setting Options

Options control things like the color and border width of a widget. Options can be set in three ways:

#### At object creation time, using keyword arguments

```
fred = Button(self, fg = "red", bg = "blue")
```

#### After object creation, treating the option name like a dictionary index

```
fred["fg"] = "red"
fred["bg"] = "blue"
```

#### Use the `config()` method to update multiple attrs subsequent to object creation

```
fred.config(fg = "red", bg = "blue")
```

For a complete explanation of a given option and its behavior, see the Tk man pages for the widget in question.

Note that the man pages list “STANDARD OPTIONS” and “WIDGET SPECIFIC OPTIONS” for each widget. The former is a list of options that are common to many widgets, the latter are the options that are idiosyncratic to that particular widget. The Standard Options are documented on the *options(3)* man page.

No distinction between standard and widget-specific options is made in this document. Some options don’t apply to some kinds of widgets. Whether a given widget responds to a particular option depends on the class of the widget; buttons have a `command` option, labels do not.

The options supported by a given widget are listed in that widget’s man page, or can be queried at runtime by calling the `config()` method without arguments, or by calling the `keys()` method on that widget. The return value of these calls is a dictionary whose key is the name of the option as a string (for example, `'relief'`) and whose values are 5-tuples.

Some options, like `bg` are synonyms for common options with long names (`bg` is shorthand for “background”). Passing the `config()` method the name of a shorthand option will return a 2-tuple, not 5-tuple. The 2-tuple passed back will contain the name of the synonym and the “real” option (such as `('bg', 'background')`).

Index	Meaning	Example
0	option name	<code>'relief'</code>
1	option name for database lookup	<code>'relief'</code>
2	option class for database lookup	<code>'Relief'</code>
3	default value	<code>'raised'</code>
4	current value	<code>'groove'</code>

Example:

```
>>> print fred.config()
{'relief' : ('relief', 'relief', 'Relief', 'raised', 'groove')}
```

Of course, the dictionary printed will include all the options available and their values. This is meant only as an example.

## The Packer

The packer is one of Tk's geometry-management mechanisms. Geometry managers are used to specify the relative positioning of the positioning of widgets within their container - their mutual *master*. In contrast to the more cumbersome *placer* (which is used less commonly, and we do not cover here), the packer takes qualitative relationship specification - *above, to the left of, filling, etc* - and works everything out to determine the exact placement coordinates for you.

The size of any *master* widget is determined by the size of the "slave widgets" inside. The packer is used to control where slave widgets appear inside the master into which they are packed. You can pack widgets into frames, and frames into other frames, in order to achieve the kind of layout you desire. Additionally, the arrangement is dynamically adjusted to accommodate incremental changes to the configuration, once it is packed.

Note that widgets do not appear until they have had their geometry specified with a geometry manager. It's a common early mistake to leave out the geometry specification, and then be surprised when the widget is created but nothing appears. A widget will appear only after it has had, for example, the packer's `pack()` method applied to it.

The `pack()` method can be called with keyword-option/value pairs that control where the widget is to appear within its container, and how it is to behave when the main application window is resized. Here are some examples:

```
fred.pack()                                # defaults to side = "top"
fred.pack(side = "left")
fred.pack(expand = 1)
```

## Packer Options

For more extensive information on the packer and the options that it can take, see the man pages and page 183 of John Ousterhout's book.

**anchor** Anchor type. Denotes where the packer is to place each slave in its parcel.

**expand** Boolean, 0 or 1.

**fill** Legal values: 'x', 'y', 'both', 'none'.

**ipadx and ipady** A distance - designating internal padding on each side of the slave widget.

**padx and pady** A distance - designating external padding on each side of the slave widget.

**side** Legal values are: 'left', 'right', 'top', 'bottom'.

## Coupling Widget Variables

The current-value setting of some widgets (like text entry widgets) can be connected directly to application variables by using special options. These options are `variable`, `textvariable`, `onvalue`, `offvalue`, and `value`. This connection works both ways: if the variable changes for any reason, the widget it's connected to will be updated to reflect the new value.

Unfortunately, in the current implementation of `Tkinter` it is not possible to hand over an arbitrary Python variable to a widget through a `variable` or `textvariable` option. The only kinds of variables for which this works are variables that are subclassed from a class called `Variable`, defined in the `Tkinter` module.

There are many useful subclasses of `Variable` already defined: `StringVar`, `IntVar`, `DoubleVar`, and `BooleanVar`. To read the current value of such a variable, call the `get()` method on it, and to change its value you call the `set()` method. If you follow this protocol, the widget will always track the value of the variable, with no further intervention on your part.

For example:

```
class App(Frame):
    def __init__(self, master=None):
        Frame.__init__(self, master)
        self.pack()

        self.entrythingy = Entry()
        self.entrythingy.pack()

        # here is the application variable
        self.contents = StringVar()
        # set it to some value
        self.contents.set("this is a variable")
        # tell the entry widget to watch this variable
        self.entrythingy["textvariable"] = self.contents

        # and here we get a callback when the user hits return.
        # we will have the program print out the value of the
        # application variable when the user hits return
        self.entrythingy.bind('<Key-Return>',
                              self.print_contents)

    def print_contents(self, event):
        print "hi. contents of entry is now ---->", \
              self.contents.get()
```

## The Window Manager

In Tk, there is a utility command, `wm`, for interacting with the window manager. Options to the `wm` command allow you to control things like titles, placement, icon bitmaps, and the like. In `Tkinter`, these commands have been implemented as methods on the `Wm` class. Toplevel widgets are subclassed from the `Wm` class, and so can call the `Wm` methods directly.

To get at the toplevel window that contains a given widget, you can often just refer to the widget's master. Of course if the widget has been packed inside of a frame, the master won't represent a toplevel window. To get at the toplevel window that contains an arbitrary widget, you can call the `_root()` method. This method begins with an underscore to denote the fact that this function is part of the implementation, and not an interface to Tk functionality.

Here are some examples of typical usage:

```
from Tkinter import *
class App(Frame):
    def __init__(self, master=None):
        Frame.__init__(self, master)
        self.pack()

# create the application
myapp = App()

#
# here are method calls to the window manager class
#
myapp.master.title("My Do-Nothing Application")
myapp.master.maxsize(1000, 400)
```

```
# start the program
myapp.mainloop()
```

## Tk Option Data Types

**anchor** Legal values are points of the compass: "n", "ne", "e", "se", "s", "sw", "w", "nw", and also "center".

**bitmap** There are eight built-in, named bitmaps: 'error', 'gray25', 'gray50', 'hourglass', 'info', 'questhead', 'question', 'warning'. To specify an X bitmap filename, give the full path to the file, preceded with an @, as in "@/usr/contrib/bitmap/gumby.bit".

**boolean** You can pass integers 0 or 1 or the strings "yes" or "no".

**callback** This is any Python function that takes no arguments. For example:

```
def print_it():
    print "hi there"
fred["command"] = print_it
```

**color** Colors can be given as the names of X colors in the rgb.txt file, or as strings representing RGB values in 4 bit: "#RGB", 8 bit: "#RRGGBB", 12 bit: "#RRRGGGBBB", or 16 bit: "#RRRRGGGGBBBB" ranges, where R,G,B here represent any legal hex digit. See page 160 of Ousterhout's book for details.

**cursor** The standard X cursor names from cursorfont.h can be used, without the XC\_ prefix. For example to get a hand cursor (XC\_hand2), use the string "hand2". You can also specify a bitmap and mask file of your own. See page 179 of Ousterhout's book.

**distance** Screen distances can be specified in either pixels or absolute distances. Pixels are given as numbers and absolute distances as strings, with the trailing character denoting units: c for centimetres, i for inches, m for millimetres, p for printer's points. For example, 3.5 inches is expressed as "3.5i".

**font** Tk uses a list font name format, such as {courier 10 bold}. Font sizes with positive numbers are measured in points; sizes with negative numbers are measured in pixels.

**geometry** This is a string of the form widthxheight, where width and height are measured in pixels for most widgets (in characters for widgets displaying text). For example: fred["geometry"] = "200x100".

**justify** Legal values are the strings: "left", "center", "right", and "fill".

**region** This is a string with four space-delimited elements, each of which is a legal distance (see above). For example: "2 3 4 5" and "3i 2i 4.5i 2i" and "3c 2c 4c 10.43c" are all legal regions.

**relief** Determines what the border style of a widget will be. Legal values are: "raised", "sunken", "flat", "groove", and "ridge".

**scrollcommand** This is almost always the set() method of some scrollbar widget, but can be any widget method that takes a single argument. Refer to the file Demo/tkinter/matt/canvas-with-scrollbars.py in the Python source distribution for an example.

**wrap:** Must be one of: "none", "char", or "word".

## Bindings and Events

The bind method from the widget command allows you to watch for certain events and to have a callback function trigger when that event type occurs. The form of the bind method is:

```
def bind(self, sequence, func, add='')
```

where:

**sequence** is a string that denotes the target kind of event. (See the bind man page and page 201 of John Ousterhout's book for details).

**func** is a Python function, taking one argument, to be invoked when the event occurs. An Event instance will be passed as the argument. (Functions deployed this way are commonly known as *callbacks*.)

**add** is optional, either "" or '+'. Passing an empty string denotes that this binding is to replace any other bindings that this event is associated with. Passing a '+' means that this function is to be added to the list of functions bound to this event type.

For example:

```
def turnRed(self, event):
    event.widget["activeforeground"] = "red"

self.button.bind("<Enter>", self.turnRed)
```

Notice how the widget field of the event is being accessed in the `turnRed()` callback. This field contains the widget that caught the X event. The following table lists the other event fields you can access, and how they are denoted in Tk, which can be useful when referring to the Tk man pages.

Tk	Tkinter Event Field	Tk	Tkinter Event Field
--	-----	--	-----
%f	focus	%A	char
%h	height	%E	send_event
%k	keycode	%K	keysym
%s	state	%N	keysym_num
%t	time	%T	type
%w	width	%W	widget
%x	x	%X	x_root
%y	y	%Y	y_root

### The index Parameter

A number of widgets require "index" parameters to be passed. These are used to point at a specific place in a Text widget, or to particular characters in an Entry widget, or to particular menu items in a Menu widget.

**Entry widget indexes (index, view index, etc.)** Entry widgets have options that refer to character positions in the text being displayed. You can use these Tkinter functions to access these special points in text widgets:

**AtEnd()** refers to the last position in the text

**AtInsert()** refers to the point where the text cursor is

**AtSelFirst()** indicates the beginning point of the selected text

**AtSelLast()** denotes the last point of the selected text and finally

**At(x, y)** refers to the character at pixel location *x*, *y* (with *y* not used in the case of a text entry widget, which contains a single line of text).

**Text widget indexes** The index notation for Text widgets is very rich and is best described in the Tk man pages.

**Menu indexes (menu.invoke(), menu.entryconfig(), etc.)** Some options and methods for menus manipulate specific menu entries. Anytime a menu index is needed for an option or a parameter, you may pass in:

- an integer which refers to the numeric position of the entry in the widget, counted from the top, starting with 0;
- the string 'active', which refers to the menu position that is currently under the cursor;
- the string "last" which refers to the last menu item;

- An integer preceded by @, as in @6, where the integer is interpreted as a y pixel coordinate in the menu's coordinate system;
- the string "none", which indicates no menu entry at all, most often used with `menu.activate()` to deactivate all entries, and finally,
- a text string that is pattern matched against the label of the menu entry, as scanned from the top of the menu to the bottom. Note that this index type is considered after all the others, which means that matches for menu items labelled `last`, `active`, or `none` may be interpreted as the above literals, instead.

## Images

Bitmap/Pixmap images can be created through the subclasses of `Tkinter.Image`:

- `BitmapImage` can be used for X11 bitmap data.
- `PhotoImage` can be used for GIF and PPM/PGM color bitmaps.

Either type of image is created through either the `file` or the `data` option (other options are available as well).

The image object can then be used wherever an `image` option is supported by some widget (e.g. labels, buttons, menus). In these cases, Tk will not keep a reference to the image. When the last Python reference to the image object is deleted, the image data is deleted as well, and Tk will display an empty box wherever the image was used.

## 24.2 ttk — Tk themed widgets

The `ttk` module provides access to the Tk themed widget set, which has been introduced in Tk 8.5. If Python is not compiled against Tk 8.5 code may still use this module as long as Tk is installed. However, some features provided by the new Tk, like anti-aliased font rendering under X11, window transparency (on X11 you will need a composition window manager) will be missing.

The basic idea of `ttk` is to separate, to the extent possible, the code implementing a widget's behavior from the code implementing its appearance.

### See Also:

**Tk Widget Styling Support** The document which brought up theming support for Tk

### 24.2.1 Using Ttk

To start using Ttk, import its module:

```
import ttk
```

But code like this:

```
from Tkinter import *
```

may optionally want to use this:

```
from Tkinter import *
from ttk import *
```

And then several `ttk` widgets (`Button`, `Checkbutton`, `Entry`, `Frame`, `Label`, `LabelFrame`, `Menubutton`, `PanedWindow`, `Radiobutton`, `Scale` and `Scrollbar`) will automatically substitute for the Tk widgets.

This has the direct benefit of using the new widgets, giving better look & feel across platforms, but be aware that they are not totally compatible. The main difference is that widget options such as "fg", "bg" and others related to widget styling are no longer present in Ttk widgets. Use `ttk.Style` to achieve the same (or better) styling.

**See Also:**

**Converting existing applications to use the Tile widgets** A text which talks in Tcl terms about differences typically found when converting applications to use the new widgets.

### 24.2.2 Ttk Widgets

Ttk comes with 17 widgets, 11 of which already exist in Tkinter: Button, Checkbutton, Entry, Frame, Label, LabelFrame, Menubutton, PanedWindow, Radiobutton, Scale and Scrollbar. The 6 new widget classes are: Combobox, Notebook, Progressbar, Separator, Sizegrip and Treeview. All of these classes are subclasses of Widget.

As said previously, you will notice changes in look-and-feel as well in the styling code. To demonstrate the latter, a very simple example is shown below.

Tk code:

```
l1 = Tkinter.Label(text="Test", fg="black", bg="white")
l2 = Tkinter.Label(text="Test", fg="black", bg="white")
```

Corresponding Ttk code:

```
style = ttk.Style()
style.configure("BW.TLabel", foreground="black", background="white")

l1 = ttk.Label(text="Test", style="BW.TLabel")
l2 = ttk.Label(text="Test", style="BW.TLabel")
```

For more information about `TtkStyling` read the `Style` class documentation.

### 24.2.3 Widget

`ttk.Widget` defines standard options and methods supported by Tk themed widgets and is not supposed to be directly instantiated.

#### Standard Options

All the `ttk` widgets accept the following options:

Option	Description
class	Specifies the window class. The class is used when querying the option database for the window's other options, to determine the default bindtags for the window, and to select the widget's default layout and style. This is a read-only option which may only be specified when the window is created.
cursor	Specifies the mouse cursor to be used for the widget. If set to the empty string (the default), the cursor is inherited from the parent widget.
take-focus	Determines whether the window accepts the focus during keyboard traversal. 0, 1 or an empty string is returned. If 0, the window should be skipped entirely during keyboard traversal. If 1, the window should receive the input focus as long as it is viewable. An empty string means that the traversal scripts make the decision about whether or not to focus on the window.
style	May be used to specify a custom widget style.

## Scrollable Widget Options

The following options are supported by widgets that are controlled by a scrollbar.

option	description
xscroll-command	Used to communicate with horizontal scrollbars. When the view in the widget's window changes, the widget will generate a Tcl command based on the scrollcommand. Usually this option consists of the <code>Scrollbar.set()</code> method of some scrollbar. This will cause the scrollbar to be updated whenever the view in the window changes.
yscroll-command	Used to communicate with vertical scrollbars. For more information, see above.

## Label Options

The following options are supported by labels, buttons and other button-like widgets.

option	description
text	Specifies a text string to be displayed inside the widget.
textvariable	Specifies a name whose value will be used in place of the text option resource.
underline	If set, specifies the index (0-based) of a character to underline in the text string. The underline character is used for mnemonic activation.
image	Specifies an image to display. This is a list of 1 or more elements. The first element is the default image name. The rest of the list is a sequence of statespec/value pairs as defined by <code>Style.map()</code> , specifying different images to use when the widget is in a particular state or a combination of states. All images in the list should have the same size.
compound	Specifies how to display the image relative to the text, in the case both text and image options are present. Valid values are: <ul style="list-style-type: none"> <li>• text: display text only</li> <li>• image: display image only</li> <li>• top, bottom, left, right: display image above, below, left of, or right of the text, respectively.</li> <li>• none: the default. display the image if present, otherwise the text.</li> </ul>
width	If greater than zero, specifies how much space, in character widths, to allocate for the text label; if less than zero, specifies a minimum width. If zero or unspecified, the natural width of the text label is used.

## Compatibility Options

option	description
state	May be set to "normal" or "disabled" to control the "disabled" state bit. This is a write-only option: setting it changes the widget state, but the <code>Widget.state()</code> method does not affect this option.

## Widget States

The widget state is a bitmap of independent state flags.

flag	description
active	The mouse cursor is over the widget and pressing a mouse button will cause some action to occur.
dis-abled	Widget is disabled under program control.
focus	Widget has keyboard focus.
pressed	Widget is being pressed.
se-lected	“On”, “true”, or “current” for things like Checkbuttons and radiobuttons.
back-ground	Windows and Mac have a notion of an “active” or foreground window. The <i>background</i> state is set for widgets in a background window, and cleared for those in the foreground window.
read-only	Widget should not allow user modification.
alter-nate	A widget-specific alternate display format.
in-valid	The widget’s value is invalid.

A state specification is a sequence of state names, optionally prefixed with an exclamation point indicating that the bit is off.

## ttk.Widget

Besides the methods described below, the `ttk.Widget` class supports the `Tkinter.Widget.cget()` and `Tkinter.Widget.configure()` methods.

**class** `ttk.Widget`

**identify** (*x, y*)

Returns the name of the element at position *x y*, or the empty string if the point does not lie within any element.

*x* and *y* are pixel coordinates relative to the widget.

**instate** (*statespec, callback=None, \*args, \*\*kw*)

Test the widget’s state. If a callback is not specified, returns True if the widget state matches *statespec* and False otherwise. If callback is specified then it is called with *args* if widget state matches *statespec*.

**state** ([*statespec=None* ])

Modify or read widget state. If *statespec* is specified, sets the widget state accordingly and returns a new *statespec* indicating which flags were changed. If *statespec* is not specified, returns the currently-enabled state flags.

*statespec* will usually be a list or a tuple.

### 24.2.4 Combobox

The `ttk.Combobox` widget combines a text field with a pop-down list of values. This widget is a subclass of `Entry`.

Besides the methods inherited from `Widget` (`Widget.cget()`, `Widget.configure()`, `Widget.identify()`, `Widget.instate()` and `Widget.state()`) and those inherited from `Entry` (`Entry.bbox()`, `Entry.delete()`, `Entry.icursor()`, `Entry.index()`, `Entry.inset()`, `Entry.selection()`, `Entry.xview()`), this class has some other methods, described at `ttk.Combobox`.

## Options

This widget accepts the following options:

option	description
exports-selection	Boolean value. If set, the widget selection is linked to the Window Manager selection (which can be returned by invoking <code>Misc.selection_get()</code> , for example).
justify	Specifies how the text is aligned within the widget. One of “left”, “center”, or “right”.
height	Specifies the height of the pop-down listbox, in rows.
post-command	A script (possibly registered with <code>Misc.register()</code> ) that is called immediately before displaying the values. It may specify which values to display.
state	One of “normal”, “readonly”, or “disabled”. In the “readonly” state, the value may not be edited directly, and the user can only select one of the values from the dropdown list. In the “normal” state, the text field is directly editable. In the “disabled” state, no interaction is possible.
textvariable	Specifies a name whose value is linked to the widget value. Whenever the value associated with that name changes, the widget value is updated, and vice versa. See <code>Tkinter.StringVar</code> .
values	Specifies the list of values to display in the drop-down listbox.
width	Specifies an integer value indicating the desired width of the entry window, in average-size characters of the widget’s font.

## Virtual events

The combobox widget generates a `<<ComboboxSelected>>` virtual event when the user selects an element from the list of values.

## ttk.Combobox

**class** `ttk.Combobox`

**current** (`[newindex=None]`)

If `newindex` is specified, sets the combobox value to the element position `newindex`. Otherwise, returns the index of the current value or -1 if the current value is not in the values list.

**get** ()

Returns the current value of the combobox.

**set** (`value`)

Sets the value of the combobox to `value`.

## 24.2.5 Notebook

The Tk Notebook widget manages a collection of windows and displays a single one at a time. Each child window is associated with a tab, which the user may select to change the currently-displayed window.

## Options

This widget accepts the following specific options:

option	description
height	If present and greater than zero, specifies the desired height of the pane area (not including internal padding or tabs). Otherwise, the maximum height of all panes is used.
padding	Specifies the amount of extra space to add around the outside of the notebook. The padding is a list of up to four length specifications: left top right bottom. If fewer than four elements are specified, bottom defaults to top, right defaults to left, and top defaults to left.
width	If present and greater than zero, specifies the desired width of the pane area (not including internal padding). Otherwise, the maximum width of all panes is used.

## Tab Options

There are also specific options for tabs:

option	description
state	Either “normal”, “disabled” or “hidden”. If “disabled”, then the tab is not selectable. If “hidden”, then the tab is not shown.
sticky	Specifies how the child window is positioned within the pane area. Value is a string containing zero or more of the characters “n”, “s”, “e” or “w”. Each letter refers to a side (north, south, east or west) that the child window will stick to, as per the <code>grid()</code> geometry manager.
padding	Specifies the amount of extra space to add between the notebook and this pane. Syntax is the same as for the option padding used by this widget.
text	Specifies a text to be displayed in the tab.
image	Specifies an image to display in the tab. See the option image described in <a href="#">Widget</a> .
compound	Specifies how to display the image relative to the text, in the case both text and image options are present. See <a href="#">Label Options</a> for legal values.
underline	Specifies the index (0-based) of a character to underline in the text string. The underlined character is used for mnemonic activation if <code>Notebook.enable_traversal()</code> is called.

## Tab Identifiers

The `tab_id` present in several methods of `ttk.Notebook` may take any of the following forms:

- An integer between zero and the number of tabs.
- The name of a child window.
- A positional specification of the form “@x,y”, which identifies the tab.
- The literal string “current”, which identifies the currently-selected tab.
- The literal string “end”, which returns the number of tabs (only valid for `Notebook.index()`).

## Virtual Events

This widget generates a <<**NotebookTabChanged**>> virtual event after a new tab is selected.

**ttk.Notebook****class** `ttk.Notebook`**add** (*child*, *\*\*kw*)

Adds a new tab to the notebook.

If window is currently managed by the notebook but hidden, it is restored to its previous position.

See [Tab Options](#) for the list of available options.

**forget** (*tab\_id*)

Removes the tab specified by *tab\_id*, unmaps and unmanages the associated window.

**hide** (*tab\_id*)

Hides the tab specified by *tab\_id*.

The tab will not be displayed, but the associated window remains managed by the notebook and its configuration remembered. Hidden tabs may be restored with the `add()` command.

**identify** (*x*, *y*)

Returns the name of the tab element at position *x*, *y*, or the empty string if none.

**index** (*tab\_id*)

Returns the numeric index of the tab specified by *tab\_id*, or the total number of tabs if *tab\_id* is the string "end".

**insert** (*pos*, *child*, *\*\*kw*)

Inserts a pane at the specified position.

*pos* is either the string "end", an integer index, or the name of a managed child. If *child* is already managed by the notebook, moves it to the specified position.

See [Tab Options](#) for the list of available options.

**select** (*[tab\_id]*)

Selects the specified *tab\_id*.

The associated child window will be displayed, and the previously-selected window (if different) is un-mapped. If *tab\_id* is omitted, returns the widget name of the currently selected pane.

**tab** (*tab\_id*, *option=None*, *\*\*kw*)

Query or modify the options of the specific *tab\_id*.

If *kw* is not given, returns a dictionary of the tab option values. If *option* is specified, returns the value of that *option*. Otherwise, sets the options to the corresponding values.

**tabs** ()

Returns a list of windows managed by the notebook.

**enable\_traversal** ()

Enable keyboard traversal for a toplevel window containing this notebook.

This will extend the bindings for the toplevel window containing the notebook as follows:

- Control-Tab: selects the tab following the currently selected one.
- Shift-Control-Tab: selects the tab preceding the currently selected one.
- Alt-K: where K is the mnemonic (underlined) character of any tab, will select that tab.

Multiple notebooks in a single toplevel may be enabled for traversal, including nested notebooks. However, notebook traversal only works properly if all panes have the notebook they are in as master.

## 24.2.6 Progressbar

The `ttk.Progressbar` widget shows the status of a long-running operation. It can operate in two modes: determinate mode shows the amount completed relative to the total amount of work to be done, and indeterminate mode provides an animated display to let the user know that something is happening.

### Options

This widget accepts the following specific options:

option	description
orient	One of “horizontal” or “vertical”. Specifies the orientation of the progress bar.
length	Specifies the length of the long axis of the progress bar (width if horizontal, height if vertical).
mode	One of “determinate” or “indeterminate”.
maximum	A number specifying the maximum value. Defaults to 100.
value	The current value of the progress bar. In “determinate” mode, this represents the amount of work completed. In “indeterminate” mode, it is interpreted as modulo <i>maximum</i> ; that is, the progress bar completes one “cycle” when its value increases by <i>maximum</i> .
variable	A name which is linked to the option value. If specified, the value of the progress bar is automatically set to the value of this name whenever the latter is modified.
phase	Read-only option. The widget periodically increments the value of this option whenever its value is greater than 0 and, in determinate mode, less than maximum. This option may be used by the current theme to provide additional animation effects.

### ttk.Progressbar

**class** `ttk.Progressbar`

**start** (`[interval]`)

Begin autoincrement mode: schedules a recurring timer event that calls `Progressbar.step()` every *interval* milliseconds. If omitted, *interval* defaults to 50 milliseconds.

**step** (`[amount]`)

Increments the progress bar’s value by *amount*.

*amount* defaults to 1.0 if omitted.

**stop** ()

Stop autoincrement mode: cancels any recurring timer event initiated by `Progressbar.start()` for this progress bar.

## 24.2.7 Separator

The `ttk.Separator` widget displays a horizontal or vertical separator bar.

It has no other methods besides the ones inherited from `ttk.Widget`.

## Options

This widget accepts the following specific option:

option	description
orient	One of “horizontal” or “vertical”. Specifies the orientation of the separator.

### 24.2.8 Sizegrip

The `ttk.Sizegrip` widget (also known as a grow box) allows the user to resize the containing toplevel window by pressing and dragging the grip.

This widget has neither specific options nor specific methods, besides the ones inherited from `ttk.Widget`.

#### Platform-specific notes

- On Mac OS X, toplevel windows automatically include a built-in size grip by default. Adding a `Sizegrip` is harmless, since the built-in grip will just mask the widget.

#### Bugs

- If the containing toplevel’s position was specified relative to the right or bottom of the screen (e.g. `...()`), the `Sizegrip` widget will not resize the window.
- This widget supports only “southeast” resizing.

### 24.2.9 Treeview

The `ttk.Treeview` widget displays a hierarchical collection of items. Each item has a textual label, an optional image, and an optional list of data values. The data values are displayed in successive columns after the tree label.

The order in which data values are displayed may be controlled by setting the widget option `displaycolumns`. The tree widget can also display column headings. Columns may be accessed by number or symbolic names listed in the widget option `columns`. See [Column Identifiers](#).

Each item is identified by a unique name. The widget will generate item IDs if they are not supplied by the caller. There is a distinguished root item, named `{}`. The root item itself is not displayed; its children appear at the top level of the hierarchy.

Each item also has a list of tags, which can be used to associate event bindings with individual items and control the appearance of the item.

The `Treeview` widget supports horizontal and vertical scrolling, according to the options described in [Scrollable Widget Options](#) and the methods `Treeview.xview()` and `Treeview.yview()`.

## Options

This widget accepts the following specific options:

option	description
columns	A list of column identifiers, specifying the number of columns and their names.
displaycolumns	A list of column identifiers (either symbolic or integer indices) specifying which data columns are displayed and the order in which they appear, or the string “#all”.
height	Specifies the number of rows which should be visible. Note: the requested width is determined from the sum of the column widths.
padding	Specifies the internal padding for the widget. The padding is a list of up to four length specifications.
selectmode	Controls how the built-in class bindings manage the selection. One of “extended”, “browse” or “none”. If set to “extended” (the default), multiple items may be selected. If “browse”, only a single item will be selected at a time. If “none”, the selection will not be changed. Note that the application code and tag bindings can set the selection however they wish, regardless of the value of this option.
show	A list containing zero or more of the following values, specifying which elements of the tree to display. <ul style="list-style-type: none"> <li>tree: display tree labels in column #0.</li> <li>headings: display the heading row.</li> </ul> The default is “tree headings”, i.e., show all elements. <b>Note:</b> Column #0 always refers to the tree column, even if show=“tree” is not specified.

### Item Options

The following item options may be specified for items in the insert and item widget commands.

option	description
text	The textual label to display for the item.
image	A Tk Image, displayed to the left of the label.
values	The list of values associated with the item. Each item should have the same number of values as the widget option columns. If there are fewer values than columns, the remaining values are assumed empty. If there are more values than columns, the extra values are ignored.
open	True/False value indicating whether the item’s children should be displayed or hidden.
tags	A list of tags associated with this item.

### Tag Options

The following options may be specified on tags:

option	description
foreground	Specifies the text foreground color.
background	Specifies the cell or item background color.
font	Specifies the font to use when drawing text.
image	Specifies the item image, in case the item’s image option is empty.

### Column Identifiers

Column identifiers take any of the following forms:

- A symbolic name from the list of columns option.

- An integer *n*, specifying the *n*th data column.
- A string of the form *#n*, where *n* is an integer, specifying the *n*th display column.

Notes:

- Item's option values may be displayed in a different order than the order in which they are stored.
- Column #0 always refers to the tree column, even if `show="tree"` is not specified.

A data column number is an index into an item's option values list; a display column number is the column number in the tree where the values are displayed. Tree labels are displayed in column #0. If option `displaycolumns` is not set, then data column *n* is displayed in column *#n+1*. Again, **column #0 always refers to the tree column.**

## Virtual Events

The Treeview widget generates the following virtual events.

event	description
<<TreeviewSelect>>	Generated whenever the selection changes.
<<TreeviewOpen>>	Generated just before settings the focus item to <code>open=True</code> .
<<TreeviewClose>>	Generated just after setting the focus item to <code>open=False</code> .

The `Treeview.focus()` and `Treeview.selection()` methods can be used to determine the affected item or items.

## ttk.Treeview

class `ttk.Treeview`

**bbox** (*item*, *column=None*)

Returns the bounding box (relative to the treeview widget's window) of the specified *item* in the form (*x*, *y*, *width*, *height*).

If *column* is specified, returns the bounding box of that cell. If the *item* is not visible (i.e., if it is a descendant of a closed item or is scrolled offscreen), returns an empty string.

**get\_children** ([*item* ])

Returns the list of children belonging to *item*.

If *item* is not specified, returns root children.

**set\_children** (*item*, *\*newchildren*)

Replaces *item*'s child with *newchildren*.

Children present in *item* that are not present in *newchildren* are detached from the tree. No items in *newchildren* may be an ancestor of *item*. Note that not specifying *newchildren* results in detaching *item*'s children.

**column** (*column*, *option=None*, *\*\*kw*)

Query or modify the options for the specified *column*.

If *kw* is not given, returns a dict of the column option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- **id** Returns the column name. This is a read-only option.
- **anchor: One of the standard Tk anchor values.** Specifies how the text in this column should be aligned with respect to the cell.

- minwidth: width** The minimum width of the column in pixels. The treeview widget will not make the column any smaller than specified by this option when the widget is resized or the user drags a column.
- stretch: True/False** Specifies whether the column's width should be adjusted when the widget is resized.
- width: width** The width of the column in pixels.

To configure the tree column, call this with `column = "#0"`

**delete** (*\*items*)

Delete all specified *items* and all their descendants.

The root item may not be deleted.

**detach** (*\*items*)

Unlinks all of the specified *items* from the tree.

The items and all of their descendants are still present, and may be reinserted at another point in the tree, but will not be displayed.

The root item may not be detached.

**exists** (*item*)

Returns True if the specified *item* is present in the tree.

**focus** ([*item=None* ])

If *item* is specified, sets the focus item to *item*. Otherwise, returns the current focus item, or '' if there is none.

**heading** (*column, option=None, \*\*kw*)

Query or modify the heading options for the specified *column*.

If *kw* is not given, returns a dict of the heading option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- text: text** The text to display in the column heading.
- image: imageName** Specifies an image to display to the right of the column heading.
- anchor: anchor** Specifies how the heading text should be aligned. One of the standard Tk anchor values.
- command: callback** A callback to be invoked when the heading label is pressed.

To configure the tree column heading, call this with `column = "#0"`.

**identify** (*component, x, y*)

Returns a description of the specified *component* under the point given by *x* and *y*, or the empty string if no such *component* is present at that position.

**identify\_row** (*y*)

Returns the item ID of the item at position *y*.

**identify\_column** (*x*)

Returns the data column identifier of the cell at position *x*.

The tree column has ID #0.

**identify\_region** (*x, y*)

Returns one of:

region	meaning
heading	Tree heading area.
separator	Space between two columns headings.
tree	The tree area.
cell	A data cell.

Availability: Tk 8.6.

**identify\_element** (*x*, *y*)

Returns the element at position *x*, *y*.

Availability: Tk 8.6.

**index** (*item*)

Returns the integer index of *item* within its parent's list of children.

**insert** (*parent*, *index*, *iid=None*, **\*\*kw**)

Creates a new item and returns the item identifier of the newly created item.

*parent* is the item ID of the parent item, or the empty string to create a new top-level item. *index* is an integer, or the value "end", specifying where in the list of parent's children to insert the new item. If *index* is less than or equal to zero, the new node is inserted at the beginning; if *index* is greater than or equal to the current number of children, it is inserted at the end. If *iid* is specified, it is used as the item identifier; *iid* must not already exist in the tree. Otherwise, a new unique identifier is generated.

See [Item Options](#) for the list of available points.

**item** (*item*[, *option*[, **\*\*kw** ] ])

Query or modify the options for the specified *item*.

If no options are given, a dict with options/values for the item is returned. If *option* is specified then the value for that option is returned. Otherwise, sets the options to the corresponding values as given by *kw*.

**move** (*item*, *parent*, *index*)

Moves *item* to position *index* in *parent*'s list of children.

It is illegal to move an item under one of its descendants. If *index* is less than or equal to zero, *item* is moved to the beginning; if greater than or equal to the number of children, it is moved to the end. If *item* was detached it is reattached.

**next** (*item*)

Returns the identifier of *item*'s next sibling, or "" if *item* is the last child of its parent.

**parent** (*item*)

Returns the ID of the parent of *item*, or "" if *item* is at the top level of the hierarchy.

**prev** (*item*)

Returns the identifier of *item*'s previous sibling, or "" if *item* is the first child of its parent.

**reattach** (*item*, *parent*, *index*)

An alias for `Treeview.move()`.

**see** (*item*)

Ensure that *item* is visible.

Sets all of *item*'s ancestors open option to True, and scrolls the widget if necessary so that *item* is within the visible portion of the tree.

**selection** ([*selop=None*[, *items=None* ] ])

If *selop* is not specified, returns selected items. Otherwise, it will act according to the following selection methods.

**selection\_set** (*items*)

*items* becomes the new selection.

**selection\_add** (*items*)

Add *items* to the selection.

**selection\_remove** (*items*)

Remove *items* from the selection.

**selection\_toggle** (*items*)

Toggle the selection state of each item in *items*.

**set** (*item*, *column=None*, *value=None*)

With one argument, returns a dictionary of column/value pairs for the specified *item*. With two arguments, returns the current value of the specified *column*. With three arguments, sets the value of given *column* in given *item* to the specified *value*.

**tag\_bind** (*tagname*, *sequence=None*, *callback=None*)

Bind a callback for the given event *sequence* to the tag *tagname*. When an event is delivered to an item, the callbacks for each of the item's tags option are called.

**tag\_configure** (*tagname*, *option=None*, *\*\*kw*)

Query or modify the options for the specified *tagname*.

If *kw* is not given, returns a dict of the option settings for *tagname*. If *option* is specified, returns the value for that *option* for the specified *tagname*. Otherwise, sets the options to the corresponding values for the given *tagname*.

**tag\_has** (*tagname*[, *item*])

If *item* is specified, returns 1 or 0 depending on whether the specified *item* has the given *tagname*. Otherwise, returns a list of all items that have the specified tag.

Availability: Tk 8.6

**xview** (*\*args*)

Query or modify horizontal position of the treeview.

**yview** (*\*args*)

Query or modify vertical position of the treeview.

## 24.2.10 Ttk Styling

Each widget in `ttk` is assigned a style, which specifies the set of elements making up the widget and how they are arranged, along with dynamic and default settings for element options. By default the style name is the same as the widget's class name, but it may be overridden by the widget's style option. If the class name of a widget is unknown, use the method `Misc.wininfo_class()` (`somewidget.wininfo_class()`).

### See Also:

**Tcl'2004 conference presentation** This document explains how the theme engine works

### class `ttk.Style`

This class is used to manipulate the style database.

**configure** (*style*, *query\_opt=None*, *\*\*kw*)

Query or set the default value of the specified option(s) in *style*.

Each key in *kw* is an option and each value is a string identifying the value for that option.

For example, to change every default button to be a flat button with some padding and a different background color do:

```

import ttk
import Tkinter

root = Tkinter.Tk()

ttk.Style().configure("TButton", padding=6, relief="flat",
    background="#ccc")

btn = ttk.Button(text="Sample")
btn.pack()

root.mainloop()

```

**map** (*style, query\_opt=None, \*\*kw*)

Query or sets dynamic values of the specified option(s) in *style*.

Each key in *kw* is an option and each value should be a list or a tuple (usually) containing statespecs grouped in tuples, lists, or something else of your preference. A statespec is a compound of one or more states and then a value.

An example:

```

import Tkinter
import ttk

root = Tkinter.Tk()

style = ttk.Style()
style.map("C.TButton",
    foreground=[('pressed', 'red'), ('active', 'blue')],
    background=[('pressed', '!disabled', 'black'), ('active', 'white')]
)

colored_btn = ttk.Button(text="Test", style="C.TButton").pack()

root.mainloop()

```

Note that the order of the (states, value) sequences for an option matters. In the previous example, if you change the order to `[('active', 'blue'), ('pressed', 'red')]` in the foreground option, for example, you would get a blue foreground when the widget is in the active or pressed states.

**lookup** (*style, option, state=None, default=None*)

Returns the value specified for *option* in *style*.

If *state* is specified, it is expected to be a sequence of one or more states. If the *default* argument is set, it is used as a fallback value in case no specification for option is found.

To check what font a Button uses by default, do:

```

import ttk

print ttk.Style().lookup("TButton", "font")

```

**layout** (*style, layoutspec=None*)

Define the widget layout for given *style*. If *layoutspec* is omitted, return the layout specification for given *style*.

*layoutspec*, if specified, is expected to be a list or some other sequence type (excluding strings), where each item should be a tuple and the first item is the layout name and the second item should have the format described in [Layouts](#).

To understand the format, see the following example (it is not intended to do anything useful):

```
import ttk
import Tkinter

root = Tkinter.Tk()

style = ttk.Style()
style.layout("TMenubutton", [
    ("Menubutton.background", None),
    ("Menubutton.button", {"children":
        [ ("Menubutton.focus", {"children":
            [ ("Menubutton.padding", {"children":
                [ ("Menubutton.label", {"side": "left", "expand": 1})]
            })]
        })]
    })],
])

mbtn = ttk.Menubutton(text='Text')
mbtn.pack()
root.mainloop()
```

**element\_create** (*elementname*, *etype*, \**args*, \*\**kw*)

Create a new element in the current theme, of the given *etype* which is expected to be either “image”, “from” or “vsapi”. The latter is only available in Tk 8.6a for Windows XP and Vista and is not described here.

If “image” is used, *args* should contain the default image name followed by statespec/value pairs (this is the imagespec), and *kw* may have the following options:

- border=padding** padding is a list of up to four integers, specifying the left, top, right, and bottom borders, respectively.
- height=height** Specifies a minimum height for the element. If less than zero, the base image’s height is used as a default.
- padding=padding** Specifies the element’s interior padding. Defaults to border’s value if not specified.
- sticky=spec** Specifies how the image is placed within the final parcel. spec contains zero or more characters “n”, “s”, “w”, or “e”.
- width=width** Specifies a minimum width for the element. If less than zero, the base image’s width is used as a default.

If “from” is used as the value of *etype*, `element_create()` will clone an existing element. *args* is expected to contain a themename, from which the element will be cloned, and optionally an element to clone from. If this element to clone from is not specified, an empty element will be used. *kw* is discarded.

**element\_names** ()

Returns the list of elements defined in the current theme.

**element\_options** (*elementname*)

Returns the list of *elementname*’s options.

**theme\_create** (*themename*, *parent=None*, *settings=None*)

Create a new theme.

It is an error if *themename* already exists. If *parent* is specified, the new theme will inherit styles, elements and layouts from the parent theme. If *settings* are present they are expected to have the same syntax used for `theme_settings()`.

**theme\_settings** (*themename*, *settings*)

Temporarily sets the current theme to *themename*, apply specified *settings* and then restore the previous theme.

Each key in *settings* is a style and each value may contain the keys ‘configure’, ‘map’, ‘layout’ and ‘element create’ and they are expected to have the same format as specified by the methods `Style.configure()`, `Style.map()`, `Style.layout()` and `Style.element_create()` respectively.

As an example, let’s change the Combobox for the default theme a bit:

```
import ttk
import Tkinter

root = Tkinter.Tk()

style = ttk.Style()
style.theme_settings("default", {
    "TCombobox": {
        "configure": {"padding": 5},
        "map": {
            "background": [("active", "green2"),
                           ("!disabled", "green4")],
            "fieldbackground": [("!disabled", "green3")],
            "foreground": [("focus", "OliveDrab1"),
                           ("!disabled", "OliveDrab2")]
        }
    }
})

combo = ttk.Combobox().pack()

root.mainloop()
```

**theme\_names** ()

Returns a list of all known themes.

**theme\_use** ([*themename*])

If *themename* is not given, returns the theme in use. Otherwise, sets the current theme to *themename*, refreshes all widgets and emits a <<ThemeChanged>> event.

## Layouts

A layout can be just None, if it takes no options, or a dict of options specifying how to arrange the element. The layout mechanism uses a simplified version of the pack geometry manager: given an initial cavity, each element is allocated a parcel. Valid options/values are:

- **side: whichside** Specifies which side of the cavity to place the element; one of top, right, bottom or left. If omitted, the element occupies the entire cavity.

- **sticky: nswe** Specifies where the element is placed inside its allocated parcel.
- **unit: 0 or 1** If set to 1, causes the element and all of its descendants to be treated as a single element for the purposes of `Widget.identify()` et al. It's used for things like scrollbar thumbs with grips.
- **children: [sublayout... ]** Specifies a list of elements to place inside the element. Each element is a tuple (or other sequence type) where the first item is the layout name, and the other is a [Layout](#).

## 24.3 Tix — Extension widgets for Tk

The `Tix` (Tk Interface Extension) module provides an additional rich set of widgets. Although the standard Tk library has many useful widgets, they are far from complete. The `Tix` library provides most of the commonly needed widgets that are missing from standard Tk: `HList`, `ComboBox`, `Control` (a.k.a. `SpinBox`) and an assortment of scrollable widgets. `Tix` also includes many more widgets that are generally useful in a wide range of applications: `NoteBook`, `FileEntry`, `PanedWindow`, etc; there are more than 40 of them.

With all these new widgets, you can introduce new interaction techniques into applications, creating more useful and more intuitive user interfaces. You can design your application by choosing the most appropriate widgets to match the special needs of your application and users.

---

**Note:** `Tix` has been renamed to `tkinter.tix` in Python 3. The `2to3` tool will automatically adapt imports when converting your sources to Python 3.

---

### See Also:

**Tix Homepage** The home page for `Tix`. This includes links to additional documentation and downloads.

**Tix Man Pages** On-line version of the man pages and reference material.

**Tix Programming Guide** On-line version of the programmer's reference material.

**Tix Development Applications** Tix applications for development of Tix and Tkinter programs. Tide applications work under Tk or Tkinter, and include **TixInspect**, an inspector to remotely modify and debug Tix/Tk/Tkinter applications.

### 24.3.1 Using Tix

**class** `Tix.Tix`(`screenName`[, `baseName`[, `className` ] ])

Toplevel widget of Tix which represents mostly the main window of an application. It has an associated Tcl interpreter.

Classes in the `Tix` module subclasses the classes in the `Tkinter` module. The former imports the latter, so to use `Tix` with Tkinter, all you need to do is to import one module. In general, you can just import `Tix`, and replace the toplevel call to `Tkinter.Tk` with `Tix.Tk`:

```
import Tix
from Tkconstants import *
root = Tix.Tk()
```

To use `Tix`, you must have the `Tix` widgets installed, usually alongside your installation of the Tk widgets. To test your installation, try the following:

```
import Tix
root = Tix.Tk()
root.tk.eval('package require Tix')
```

If this fails, you have a Tk installation problem which must be resolved before proceeding. Use the environment variable `TIX_LIBRARY` to point to the installed `Tix` library directory, and make sure you have the dynamic object library (`tix8183.dll` or `libtix8183.so`) in the same directory that contains your Tk dynamic object library (`tk8183.dll` or `libtk8183.so`). The directory with the dynamic object library should also have a file called `pkgIndex.tcl` (case sensitive), which contains the line:

```
package ifneeded Tix 8.1 [list load "[file join $dir tix8183.dll]" Tix]
```

## 24.3.2 Tix Widgets

`Tix` introduces over 40 widget classes to the `Tkinter` repertoire. There is a demo of all the `Tix` widgets in the `Demo/tix` directory of the standard distribution.

### Basic Widgets

#### **class** `Tix.Balloon`

A `Balloon` that pops up over a widget to provide help. When the user moves the cursor inside a widget to which a `Balloon` widget has been bound, a small pop-up window with a descriptive message will be shown on the screen.

#### **class** `Tix.ButtonBox`

The `ButtonBox` widget creates a box of buttons, such as is commonly used for `Ok Cancel`.

#### **class** `Tix.ComboBox`

The `ComboBox` widget is similar to the combo box control in MS Windows. The user can select a choice by either typing in the entry subwidget or selecting from the listbox subwidget.

#### **class** `Tix.Control`

The `Control` widget is also known as the `SpinBox` widget. The user can adjust the value by pressing the two arrow buttons or by entering the value directly into the entry. The new value will be checked against the user-defined upper and lower limits.

#### **class** `Tix.LabelEntry`

The `LabelEntry` widget packages an entry widget and a label into one mega widget. It can be used to simplify the creation of “entry-form” type of interface.

#### **class** `Tix.LabelFrame`

The `LabelFrame` widget packages a frame widget and a label into one mega widget. To create widgets inside a `LabelFrame` widget, one creates the new widgets relative to the `frame` subwidget and manage them inside the `frame` subwidget.

#### **class** `Tix.Meter`

The `Meter` widget can be used to show the progress of a background job which may take a long time to execute.

#### **class** `Tix.OptionMenu`

The `OptionMenu` creates a menu button of options.

#### **class** `Tix.PopupMenu`

The `PopupMenu` widget can be used as a replacement of the `tk_popup` command. The advantage of the `Tix PopupMenu` widget is it requires less application code to manipulate.

#### **class** `Tix.Select`

The `Select` widget is a container of button subwidgets. It can be used to provide radio-box or check-box style of selection options for the user.

#### **class** `Tix.StdButtonBox`

The `StdButtonBox` widget is a group of standard buttons for Motif-like dialog boxes.

### File Selectors

**class** `Tix.DirList`

The `DirList` widget displays a list view of a directory, its previous directories and its sub-directories. The user can choose one of the directories displayed in the list or change to another directory.

**class** `Tix.DirTree`

The `DirTree` widget displays a tree view of a directory, its previous directories and its sub-directories. The user can choose one of the directories displayed in the list or change to another directory.

**class** `Tix.DirSelectDialog`

The `DirSelectDialog` widget presents the directories in the file system in a dialog window. The user can use this dialog window to navigate through the file system to select the desired directory.

**class** `Tix.DirSelectBox`

The `DirSelectBox` is similar to the standard Motif(TM) directory-selection box. It is generally used for the user to choose a directory. `DirSelectBox` stores the directories mostly recently selected into a `ComboBox` widget so that they can be quickly selected again.

**class** `Tix.ExFileSelectBox`

The `ExFileSelectBox` widget is usually embedded in a `tixExFileSelectDialog` widget. It provides an convenient method for the user to select files. The style of the `ExFileSelectBox` widget is very similar to the standard file dialog on MS Windows 3.1.

**class** `Tix.FileSelectBox`

The `FileSelectBox` is similar to the standard Motif(TM) file-selection box. It is generally used for the user to choose a file. `FileSelectBox` stores the files mostly recently selected into a `ComboBox` widget so that they can be quickly selected again.

**class** `Tix.FileEntry`

The `FileEntry` widget can be used to input a filename. The user can type in the filename manually. Alternatively, the user can press the button widget that sits next to the entry, which will bring up a file selection dialog.

### Hierarchical ListBox

**class** `Tix.HList`

The `HList` widget can be used to display any data that have a hierarchical structure, for example, file system directory trees. The list entries are indented and connected by branch lines according to their places in the hierarchy.

**class** `Tix.CheckList`

The `CheckList` widget displays a list of items to be selected by the user. `CheckList` acts similarly to the Tk `checkboxbutton` or `radiobutton` widgets, except it is capable of handling many more items than `checkboxbuttons` or `radiobuttons`.

**class** `Tix.Tree`

The `Tree` widget can be used to display hierarchical data in a tree form. The user can adjust the view of the tree by opening or closing parts of the tree.

### Tabular ListBox

**class** `Tix.TList`

The `TList` widget can be used to display data in a tabular format. The list entries of a `TList` widget are similar to the entries in the Tk listbox widget. The main differences are (1) the `TList` widget can display the list entries in a two dimensional format and (2) you can use graphical images as well as multiple colors and fonts for the list entries.

## Manager Widgets

### class `Tix.PanedWindow`

The `PanedWindow` widget allows the user to interactively manipulate the sizes of several panes. The panes can be arranged either vertically or horizontally. The user changes the sizes of the panes by dragging the resize handle between two panes.

### class `Tix.ListNoteBook`

The `ListNoteBook` widget is very similar to the `TixNoteBook` widget: it can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages (windows). At one time only one of these pages can be shown. The user can navigate through these pages by choosing the name of the desired page in the `hlist` subwidget.

### class `Tix.NoteBook`

The `NoteBook` widget can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages. At one time only one of these pages can be shown. The user can navigate through these pages by choosing the visual “tabs” at the top of the `NoteBook` widget.

## Image Types

The `Tix` module adds:

- `pixmap`  capabilities to all `Tix` and `Tkinter` widgets to create color images from XPM files.
- `Compound` image types can be used to create images that consists of multiple horizontal lines; each line is composed of a series of items (texts, bitmaps, images or spaces) arranged from left to right. For example, a compound image can be used to display a bitmap and a text string simultaneously in a `Tk Button` widget.

## Miscellaneous Widgets

### class `Tix.InputOnly`

The `InputOnly` widgets are to accept inputs from the user, which can be done with the `bind` command (Unix only).

## Form Geometry Manager

In addition, `Tix` augments `Tkinter` by providing:

### class `Tix.Form`

The `Form` geometry manager based on attachment rules for all `Tk` widgets.

### 24.3.3 Tix Commands

#### class `Tix.tixCommand`

The `tix commands` provide access to miscellaneous elements of `Tix`'s internal state and the `Tix` application context. Most of the information manipulated by these methods pertains to the application as a whole, or to a screen or display, rather than to a particular window.

To view the current settings, the common usage is:

```
import Tix
root = Tix.Tk()
print root.tix_configure()
```

`tixCommand.tix_configure` (*cnf=None \*\*kw*)

Query or modify the configuration options of the Tix application context. If no option is specified, returns a dictionary all of the available options. If option is specified with no value, then the method returns a list describing the one named option (this list will be identical to the corresponding sublist of the value returned if no option is specified). If one or more option-value pairs are specified, then the method modifies the given option(s) to have the given value(s); in this case the method returns an empty string. Option may be any of the configuration options.

`tixCommand.tix_cget` (*option*)

Returns the current value of the configuration option given by *option*. Option may be any of the configuration options.

`tixCommand.tix_getbitmap` (*name*)

Locates a bitmap file of the name *name*.xpm or *name* in one of the bitmap directories (see the `tix_addbitmapdir()` method). By using `tix_getbitmap()`, you can avoid hard coding the pathnames of the bitmap files in your application. When successful, it returns the complete pathname of the bitmap file, prefixed with the character @. The returned value can be used to configure the `bitmap` option of the Tk and Tix widgets.

`tixCommand.tix_addbitmapdir` (*directory*)

Tix maintains a list of directories under which the `tix_getimage()` and `tix_getbitmap()` methods will search for image files. The standard bitmap directory is `$TIX_LIBRARY/bitmaps`. The `tix_addbitmapdir()` method adds *directory* into this list. By using this method, the image files of an applications can also be located using the `tix_getimage()` or `tix_getbitmap()` method.

`tixCommand.tix_filedialog` (*[dlgclass]*)

Returns the file selection dialog that may be shared among different calls from this application. This method will create a file selection dialog widget when it is called the first time. This dialog will be returned by all subsequent calls to `tix_filedialog()`. An optional *dlgclass* parameter can be passed as a string to specified what type of file selection dialog widget is desired. Possible options are `tix`, `FileSelectDialog` or `tixExFileSelectDialog`.

`tixCommand.tix_getimage` (*self, name*)

Locates an image file of the name *name*.xpm, *name*.xbm or *name*.ppm in one of the bitmap directories (see the `tix_addbitmapdir()` method above). If more than one file with the same name (but different extensions) exist, then the image type is chosen according to the depth of the X display: xbm images are chosen on monochrome displays and color images are chosen on color displays. By using `tix_getimage()`, you can avoid hard coding the pathnames of the image files in your application. When successful, this method returns the name of the newly created image, which can be used to configure the `image` option of the Tk and Tix widgets.

`tixCommand.tix_option_get` (*name*)

Gets the options maintained by the Tix scheme mechanism.

`tixCommand.tix_resetoptions` (*newScheme, newFontSet[, newScmPrio]*)

Resets the scheme and fontset of the Tix application to *newScheme* and *newFontSet*, respectively. This affects only those widgets created after this call. Therefore, it is best to call the `resetoptions` method before the creation of any widgets in a Tix application.

The optional parameter *newScmPrio* can be given to reset the priority level of the Tk options set by the Tix schemes.

Because of the way Tk handles the X option database, after Tix has been imported and inited, it is not possible to reset the color schemes and font sets using the `tix_config()` method. Instead, the `tix_resetoptions()` method must be used.

## 24.4 ScrolledText — Scrolled Text Widget

*Platforms:* Tk

The `ScrolledText` module provides a class of the same name which implements a basic text widget which has a vertical scroll bar configured to do the “right thing.” Using the `ScrolledText` class is a lot easier than setting up a text widget and scroll bar directly. The constructor is the same as that of the `Tkinter.Text` class.

---

**Note:** `ScrolledText` has been renamed to `tkinter.scrolledtext` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

The text widget and scrollbar are packed together in a `Frame`, and the methods of the `Grid` and `Pack` geometry managers are acquired from the `Frame` object. This allows the `ScrolledText` widget to be used directly to achieve most normal geometry management behavior.

Should more specific control be necessary, the following attributes are available:

`ScrolledText.frame`

The frame which surrounds the text and scroll bar widgets.

`ScrolledText.vbar`

The scroll bar widget.

## 24.5 turtle — Turtle graphics for Tk

### 24.5.1 Introduction

Turtle graphics is a popular way for introducing programming to kids. It was part of the original Logo programming language developed by Wally Feurzig and Seymour Papert in 1966.

Imagine a robotic turtle starting at (0, 0) in the x-y plane. After an `import turtle`, give it the command `turtle.forward(15)`, and it moves (on-screen!) 15 pixels in the direction it is facing, drawing a line as it moves. Give it the command `turtle.right(25)`, and it rotates in-place 25 degrees clockwise.

By combining together these and similar commands, intricate shapes and pictures can easily be drawn.

The `turtle` module is an extended reimplementaion of the same-named module from the Python standard distribution up to version Python 2.5.

It tries to keep the merits of the old turtle module and to be (nearly) 100% compatible with it. This means in the first place to enable the learning programmer to use all the commands, classes and methods interactively when using the module from within IDLE run with the `-n` switch.

The turtle module provides turtle graphics primitives, in both object-oriented and procedure-oriented ways. Because it uses `Tkinter` for the underlying graphics, it needs a version of Python installed with Tk support.

The object-oriented interface uses essentially two+two classes:

1. The `TurtleScreen` class defines graphics windows as a playground for the drawing turtles. Its constructor needs a `Tkinter.Canvas` or a `ScrolledCanvas` as argument. It should be used when `turtle` is used as part of some application.

The function `Screen()` returns a singleton object of a `TurtleScreen` subclass. This function should be used when `turtle` is used as a standalone tool for doing graphics. As a singleton object, inheriting from its class is not possible.

All methods of `TurtleScreen/Screen` also exist as functions, i.e. as part of the procedure-oriented interface.

2. `RawTurtle` (alias: `RawPen`) defines Turtle objects which draw on a `TurtleScreen`. Its constructor needs a `Canvas`, `ScrolledCanvas` or `TurtleScreen` as argument, so the `RawTurtle` objects know where to draw.

Derived from `RawTurtle` is the subclass `Turtle` (alias: `Pen`), which draws on “the” `Screen` - instance which is automatically created, if not already present.

All methods of `RawTurtle/Turtle` also exist as functions, i.e. part of the procedure-oriented interface.

The procedural interface provides functions which are derived from the methods of the classes `Screen` and `Turtle`. They have the same names as the corresponding methods. A screen object is automatically created whenever a function derived from a `Screen` method is called. An (unnamed) turtle object is automatically created whenever any of the functions derived from a `Turtle` method is called.

To use multiple turtles on a screen one has to use the object-oriented interface.

---

**Note:** In the following documentation the argument list for functions is given. Methods, of course, have the additional first argument `self` which is omitted here.

---

## 24.5.2 Overview over available Turtle and Screen methods

### Turtle methods

#### Turtle motion

##### Move and draw

```
forward() | fd()
backward() | bk() | back()
right() | rt()
left() | lt()
goto() | setpos() | setposition()
setx()
sety()
setheading() | seth()
home()
circle()
dot()
stamp()
clearstamp()
clearstamps()
undo()
speed()
```

##### Tell Turtle's state

```
position() | pos()
towards()
xcor()
ycor()
heading()
distance()
```

##### Setting and measurement

```
degrees()  
radians()
```

## Pen control

### Drawing state

```
pendown() | pd() | down()  
penup() | pu() | up()  
pensize() | width()  
pen()  
isdown()
```

### Color control

```
color()  
pencolor()  
fillcolor()
```

### Filling

```
fill()  
begin_fill()  
end_fill()
```

### More drawing control

```
reset()  
clear()  
write()
```

## Turtle state

### Visibility

```
showturtle() | st()  
hideturtle() | ht()  
isvisible()
```

### Appearance

```
shape()  
resizemode()  
shapeseize() | turtlesize()  
settiltangle()  
tiltangle()  
tilt()
```

## Using events

```
onclick()  
onrelease()  
ondrag()  
mainloop() | done()
```

## Special Turtle methods

```
begin_poly()  
end_poly()
```

```
get_poly()
clone()
getturtle() | getpen()
getscreen()
setundobuffer()
undobufferentries()
tracer()
window_width()
window_height()
```

## Methods of TurtleScreen/Screen

### Window control

```
bgcolor()
bgpic()
clear() | clearscreen()
reset() | resetscreen()
screensize()
setworldcoordinates()
```

### Animation control

```
delay()
tracer()
update()
```

### Using screen events

```
listen()
onkey()
onclick() | onclickscreen()
ontimer()
```

### Settings and special methods

```
mode()
colormode()
getcanvas()
getshapes()
register_shape() | addshape()
turtles()
window_height()
window_width()
```

### Methods specific to Screen

```
bye()
exitonclick()
setup()
title()
```

### 24.5.3 Methods of RawTurtle/Turtle and corresponding functions

Most of the examples in this section refer to a Turtle instance called `turtle`.

#### Turtle motion

`turtle.forward(distance)`

`turtle.fd(distance)`

**Parameters** *distance* – a number (integer or float)

Move the turtle forward by the specified *distance*, in the direction the turtle is headed.

```
>>> turtle.position()
(0.00,0.00)
>>> turtle.forward(25)
>>> turtle.position()
(25.00,0.00)
>>> turtle.forward(-75)
>>> turtle.position()
(-50.00,0.00)
```

`turtle.back(distance)`

`turtle.bk(distance)`

`turtle.backward(distance)`

**Parameters** *distance* – a number

Move the turtle backward by *distance*, opposite to the direction the turtle is headed. Do not change the turtle's heading.

```
>>> turtle.position()
(0.00,0.00)
>>> turtle.backward(30)
>>> turtle.position()
(-30.00,0.00)
```

`turtle.right(angle)`

`turtle.rt(angle)`

**Parameters** *angle* – a number (integer or float)

Turn turtle right by *angle* units. (Units are by default degrees, but can be set via the `degrees()` and `radians()` functions.) Angle orientation depends on the turtle mode, see `mode()`.

```
>>> turtle.heading()
22.0
>>> turtle.right(45)
>>> turtle.heading()
337.0
```

`turtle.left(angle)`

`turtle.lt(angle)`

**Parameters** *angle* – a number (integer or float)

Turn turtle left by *angle* units. (Units are by default degrees, but can be set via the `degrees()` and `radians()` functions.) Angle orientation depends on the turtle mode, see `mode()`.

```
>>> turtle.heading()
22.0
>>> turtle.left(45)
>>> turtle.heading()
67.0
```

```
turtle.goto(x, y=None)
turtle.setpos(x, y=None)
turtle.setposition(x, y=None)
```

### Parameters

- **x** – a number or a pair/vector of numbers
- **y** – a number or None

If *y* is None, *x* must be a pair of coordinates or a `Vec2D` (e.g. as returned by `pos()`).

Move turtle to an absolute position. If the pen is down, draw line. Do not change the turtle's orientation.

```
>>> tp = turtle.pos()
>>> tp
(0.00, 0.00)
>>> turtle.setpos(60, 30)
>>> turtle.pos()
(60.00, 30.00)
>>> turtle.setpos((20, 80))
>>> turtle.pos()
(20.00, 80.00)
>>> turtle.setpos(tp)
>>> turtle.pos()
(0.00, 0.00)
```

```
turtle.setx(x)
```

**Parameters** **x** – a number (integer or float)

Set the turtle's first coordinate to *x*, leave second coordinate unchanged.

```
>>> turtle.position()
(0.00, 240.00)
>>> turtle.setx(10)
>>> turtle.position()
(10.00, 240.00)
```

```
turtle.sety(y)
```

**Parameters** **y** – a number (integer or float)

Set the turtle's second coordinate to *y*, leave first coordinate unchanged.

```
>>> turtle.position()
(0.00, 40.00)
>>> turtle.sety(-10)
```

```
>>> turtle.position()
(0.00,-10.00)
```

```
turtle.setheading(to_angle)
turtle.seth(to_angle)
```

**Parameters** *to\_angle* – a number (integer or float)

Set the orientation of the turtle to *to\_angle*. Here are some common directions in degrees:

standard mode	logo mode
0 - east	0 - north
90 - north	90 - east
180 - west	180 - south
270 - south	270 - west

```
>>> turtle.setheading(90)
>>> turtle.heading()
90.0
```

```
turtle.home()
```

Move turtle to the origin – coordinates (0,0) – and set its heading to its start-orientation (which depends on the mode, see `mode()`).

```
>>> turtle.heading()
90.0
>>> turtle.position()
(0.00,-10.00)
>>> turtle.home()
>>> turtle.position()
(0.00,0.00)
>>> turtle.heading()
0.0
```

```
turtle.circle(radius, extent=None, steps=None)
```

#### Parameters

- **radius** – a number
- **extent** – a number (or None)
- **steps** – an integer (or None)

Draw a circle with given *radius*. The center is *radius* units left of the turtle; *extent* – an angle – determines which part of the circle is drawn. If *extent* is not given, draw the entire circle. If *extent* is not a full circle, one endpoint of the arc is the current pen position. Draw the arc in counterclockwise direction if *radius* is positive, otherwise in clockwise direction. Finally the direction of the turtle is changed by the amount of *extent*.

As the circle is approximated by an inscribed regular polygon, *steps* determines the number of steps to use. If not given, it will be calculated automatically. May be used to draw regular polygons.

```
>>> turtle.home()
>>> turtle.position()
(0.00,0.00)
>>> turtle.heading()
0.0
>>> turtle.circle(50)
```

```
>>> turtle.position()
(-0.00, 0.00)
>>> turtle.heading()
0.0
>>> turtle.circle(120, 180) # draw a semicircle
>>> turtle.position()
(0.00, 240.00)
>>> turtle.heading()
180.0
```

`turtle.dot` (*size=None, \*color*)

### Parameters

- **size** – an integer  $\geq 1$  (if given)
- **color** – a colorstring or a numeric color tuple

Draw a circular dot with diameter *size*, using *color*. If *size* is not given, the maximum of `pensize+4` and `2*pensize` is used.

```
>>> turtle.home()
>>> turtle.dot()
>>> turtle.fd(50); turtle.dot(20, "blue"); turtle.fd(50)
>>> turtle.position()
(100.00, -0.00)
>>> turtle.heading()
0.0
```

`turtle.stamp` ()

Stamp a copy of the turtle shape onto the canvas at the current turtle position. Return a `stamp_id` for that stamp, which can be used to delete it by calling `clearstamp(stamp_id)`.

```
>>> turtle.color("blue")
>>> turtle.stamp()
11
>>> turtle.fd(50)
```

`turtle.clearstamp` (*stampid*)

**Parameters** **stampid** – an integer, must be return value of previous `stamp()` call

Delete stamp with given *stampid*.

```
>>> turtle.position()
(150.00, -0.00)
>>> turtle.color("blue")
>>> astamp = turtle.stamp()
>>> turtle.fd(50)
>>> turtle.position()
(200.00, -0.00)
>>> turtle.clearstamp(astamp)
>>> turtle.position()
(200.00, -0.00)
```

`turtle.clearstamps` (*n=None*)

**Parameters** *n* – an integer (or None)

Delete all or first/last *n* of turtle’s stamps. If *n* is None, delete all stamps, if *n* > 0 delete first *n* stamps, else if *n* < 0 delete last *n* stamps.

```
>>> for i in range(8):
...     turtle.stamp(); turtle.fd(30)
13
14
15
16
17
18
19
20
>>> turtle.clearstamps(2)
>>> turtle.clearstamps(-2)
>>> turtle.clearstamps()
```

`turtle.undo()`

Undo (repeatedly) the last turtle action(s). Number of available undo actions is determined by the size of the undobuffer.

```
>>> for i in range(4):
...     turtle.fd(50); turtle.lt(80)
...
>>> for i in range(8):
...     turtle.undo()
```

`turtle.speed(speed=None)`

**Parameters** *speed* – an integer in the range 0..10 or a speedstring (see below)

Set the turtle’s speed to an integer value in the range 0..10. If no argument is given, return current speed.

If input is a number greater than 10 or smaller than 0.5, speed is set to 0. Speedstrings are mapped to speedvalues as follows:

- “fastest”: 0
- “fast”: 10
- “normal”: 6
- “slow”: 3
- “slowest”: 1

Speeds from 1 to 10 enforce increasingly faster animation of line drawing and turtle turning.

Attention: *speed* = 0 means that *no* animation takes place. forward/back makes turtle jump and likewise left/right make the turtle turn instantly.

```
>>> turtle.speed()
3
>>> turtle.speed('normal')
>>> turtle.speed()
6
>>> turtle.speed(9)
```

```
>>> turtle.speed()
9
```

### Tell Turtle's state

`turtle.position()`

`turtle.pos()`

Return the turtle's current location (x,y) (as a `Vec2D` vector).

```
>>> turtle.pos()
(440.00, -0.00)
```

`turtle.towards(x, y=None)`

#### Parameters

- **x** – a number or a pair/vector of numbers or a turtle instance
- **y** – a number if *x* is a number, else `None`

Return the angle between the line from turtle position to position specified by (x,y), the vector or the other turtle. This depends on the turtle's start orientation which depends on the mode - "standard"/"world" or "logo").

```
>>> turtle.goto(10, 10)
>>> turtle.towards(0, 0)
225.0
```

`turtle.xcor()`

Return the turtle's x coordinate.

```
>>> turtle.home()
>>> turtle.left(50)
>>> turtle.forward(100)
>>> turtle.pos()
(64.28, 76.60)
>>> print turtle.xcor()
64.2787609687
```

`turtle.ycor()`

Return the turtle's y coordinate.

```
>>> turtle.home()
>>> turtle.left(60)
>>> turtle.forward(100)
>>> print turtle.pos()
(50.00, 86.60)
>>> print turtle.ycor()
86.6025403784
```

`turtle.heading()`

Return the turtle's current heading (value depends on the turtle mode, see `mode()`).

```
>>> turtle.home()
>>> turtle.left(67)
```

```
>>> turtle.heading()
67.0
```

`turtle.distance(x, y=None)`

#### Parameters

- **x** – a number or a pair/vector of numbers or a turtle instance
- **y** – a number if *x* is a number, else None

Return the distance from the turtle to (x,y), the given vector, or the given other turtle, in turtle step units.

```
>>> turtle.home()
>>> turtle.distance(30, 40)
50.0
>>> turtle.distance((30, 40))
50.0
>>> joe = Turtle()
>>> joe.forward(77)
>>> turtle.distance(joe)
77.0
```

### Settings for measurement

`turtle.degrees(fullcircle=360.0)`

**Parameters** **fullcircle** – a number

Set angle measurement units, i.e. set number of “degrees” for a full circle. Default value is 360 degrees.

```
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0
```

Change angle measurement unit to grad (also known as gon, grade, or gradian and equals 1/100-th of the right angle.)

```
>>> turtle.degrees(400.0)
>>> turtle.heading()
100.0
>>> turtle.degrees(360)
>>> turtle.heading()
90.0
```

`turtle.radians()`

Set the angle measurement units to radians. Equivalent to `degrees(2*math.pi)`.

```
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0
>>> turtle.radians()
>>> turtle.heading()
1.5707963267948966
```

### Pen control

#### Drawing state

```
turtle.pendown()
```

```
turtle.pd()
```

```
turtle.down()
```

Pull the pen down – drawing when moving.

```
turtle.penup()
```

```
turtle.pu()
```

```
turtle.up()
```

Pull the pen up – no drawing when moving.

```
turtle.pensize(width=None)
```

```
turtle.width(width=None)
```

**Parameters** *width* – a positive number

Set the line thickness to *width* or return it. If *resizemode* is set to “auto” and *turtleshape* is a polygon, that polygon is drawn with the same line thickness. If no argument is given, the current pensize is returned.

```
>>> turtle.pensize()
```

```
1
```

```
>>> turtle.pensize(10) # from here on lines of width 10 are drawn
```

```
turtle.pen(pen=None, **pendict)
```

#### Parameters

- **pen** – a dictionary with some or all of the below listed keys
- **pendict** – one or more keyword-arguments with the below listed keys as keywords

Return or set the pen’s attributes in a “pen-dictionary” with the following key/value pairs:

- “shown”: True/False
- “pendown”: True/False
- “pencolor”: color-string or color-tuple
- “fillcolor”: color-string or color-tuple
- “pensize”: positive number
- “speed”: number in range 0..10
- “resizemode”: “auto” or “user” or “noresize”
- “stretchfactor”: (positive number, positive number)
- “outline”: positive number
- “tilt”: number

This dictionary can be used as argument for a subsequent call to `pen()` to restore the former pen-state. Moreover one or more of these attributes can be provided as keyword-arguments. This can be used to set several pen attributes in one statement.

```
>>> turtle.pen(fillcolor="black", pencolor="red", pensize=10)
```

```
>>> sorted(turtle.pen().items())
```

```
[('fillcolor', 'black'), ('outline', 1), ('pencolor', 'red'),
```

```

('pendown', True), ('pensize', 10), ('resizemode', 'noresize'),
('shown', True), ('speed', 9), ('stretchfactor', (1, 1)), ('tilt', 0)]
>>> penstate=turtle.pen()
>>> turtle.color("yellow", "")
>>> turtle.penup()
>>> sorted(turtle.pen().items())
[('fillcolor', ''), ('outline', 1), ('pencolor', 'yellow'),
 ('pendown', False), ('pensize', 10), ('resizemode', 'noresize'),
 ('shown', True), ('speed', 9), ('stretchfactor', (1, 1)), ('tilt', 0)]
>>> turtle.pen(penstate, fillcolor="green")
>>> sorted(turtle.pen().items())
[('fillcolor', 'green'), ('outline', 1), ('pencolor', 'red'),
 ('pendown', True), ('pensize', 10), ('resizemode', 'noresize'),
 ('shown', True), ('speed', 9), ('stretchfactor', (1, 1)), ('tilt', 0)]

```

`turtle.isdown()`

Return True if pen is down, False if it's up.

```

>>> turtle.penup()
>>> turtle.isdown()
False
>>> turtle.pendown()
>>> turtle.isdown()
True

```

## Color control

`turtle.pencolor(*args)`

Return or set the pencolor.

Four input formats are allowed:

**pencolor()** Return the current pencolor as color specification string or as a tuple (see example). May be used as input to another color/pencolor/fillcolor call.

**pencolor(colorstring)** Set pencolor to *colorstring*, which is a Tk color specification string, such as "red", "yellow", or "#33cc8c".

**pencolor(r, g, b)** Set pencolor to the RGB color represented by the tuple of *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode, where colormode is either 1.0 or 255 (see `colormode()`).

**pencolor(r, g, b)**

Set pencolor to the RGB color represented by *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode.

If `turtleshape` is a polygon, the outline of that polygon is drawn with the newly set pencolor.

```

>>> colormode()
1.0
>>> turtle.pencolor()
'red'
>>> turtle.pencolor("brown")
>>> turtle.pencolor()
'brown'
>>> tup = (0.2, 0.8, 0.55)

```

```
>>> turtle.pencolor(tup)
>>> turtle.pencolor()
(0.2, 0.8, 0.5490196078431373)
>>> colormode(255)
>>> turtle.pencolor()
(51, 204, 140)
>>> turtle.pencolor('#32c18f')
>>> turtle.pencolor()
(50, 193, 143)
```

`turtle.fillcolor(*args)`

Return or set the fillcolor.

Four input formats are allowed:

**fillcolor()** Return the current fillcolor as color specification string, possibly in tuple format (see example). May be used as input to another color/pencolor/fillcolor call.

**fillcolor(colorstring)** Set fillcolor to *colorstring*, which is a Tk color specification string, such as "red", "yellow", or "#33cc8c".

**fillcolor(r, g, b)** Set fillcolor to the RGB color represented by the tuple of *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode, where colormode is either 1.0 or 255 (see `colormode()`).

**fillcolor(r, g, b)**

Set fillcolor to the RGB color represented by *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode.

If turtleshape is a polygon, the interior of that polygon is drawn with the newly set fillcolor.

```
>>> turtle.fillcolor("violet")
>>> turtle.fillcolor()
'violet'
>>> col = turtle.pencolor()
>>> col
(50, 193, 143)
>>> turtle.fillcolor(col)
>>> turtle.fillcolor()
(50, 193, 143)
>>> turtle.fillcolor('#ffffff')
>>> turtle.fillcolor()
(255, 255, 255)
```

`turtle.color(*args)`

Return or set pencolor and fillcolor.

Several input formats are allowed. They use 0 to 3 arguments as follows:

**color()** Return the current pencolor and the current fillcolor as a pair of color specification strings or tuples as returned by `pencolor()` and `fillcolor()`.

**color(colorstring), color((r, g, b)), color(r, g, b)** Inputs as in `pencolor()`, set both, fillcolor and pencolor, to the given value.

**color(colorstring1, colorstring2), color((r1, g1, b1), (r2, g2, b2))**

Equivalent to `pencolor(colorstring1)` and `fillcolor(colorstring2)` and analogously if the other input format is used.

If `turtleshape` is a polygon, outline and interior of that polygon is drawn with the newly set colors.

```
>>> turtle.color("red", "green")
>>> turtle.color()
('red', 'green')
>>> color("#285078", "#a0c8f0")
>>> color()
((40, 80, 120), (160, 200, 240))
```

See also: Screen method `colormode()`.

## Filling

`turtle.fill(flag)`

**Parameters** `flag` – True/False (or 1/0 respectively)

Call `fill(True)` before drawing the shape you want to fill, and `fill(False)` when done. When used without argument: return fillstate (True if filling, False else).

```
>>> turtle.fill(True)
>>> for _ in range(3):
...     turtle.forward(100)
...     turtle.left(120)
...
>>> turtle.fill(False)
```

`turtle.begin_fill()`

Call just before drawing a shape to be filled. Equivalent to `fill(True)`.

`turtle.end_fill()`

Fill the shape drawn after the last call to `begin_fill()`. Equivalent to `fill(False)`.

```
>>> turtle.color("black", "red")
>>> turtle.begin_fill()
>>> turtle.circle(80)
>>> turtle.end_fill()
```

## More drawing control

`turtle.reset()`

Delete the turtle's drawings from the screen, re-center the turtle and set variables to the default values.

```
>>> turtle.goto(0, -22)
>>> turtle.left(100)
>>> turtle.position()
(0.00, -22.00)
>>> turtle.heading()
100.0
>>> turtle.reset()
>>> turtle.position()
(0.00, 0.00)
>>> turtle.heading()
0.0
```

`turtle.clear()`

Delete the turtle's drawings from the screen. Do not move turtle. State and position of the turtle as well as drawings of other turtles are not affected.

`turtle.write(arg, move=False, align="left", font=("Arial", 8, "normal"))`

### Parameters

- **arg** – object to be written to the TurtleScreen
- **move** – True/False
- **align** – one of the strings “left”, “center” or right”
- **font** – a triple (fontname, fontsize, fonttype)

Write text - the string representation of *arg* - at the current turtle position according to *align* (“left”, “center” or right”) and with the given font. If *move* is True, the pen is moved to the bottom-right corner of the text. By default, *move* is False.

```
>>> turtle.write("Home = ", True, align="center")
>>> turtle.write((0,0), True)
```

## Turtle state

### Visibility

`turtle.hideturtle()`

`turtle.ht()`

Make the turtle invisible. It's a good idea to do this while you're in the middle of doing some complex drawing, because hiding the turtle speeds up the drawing observably.

```
>>> turtle.hideturtle()
```

`turtle.showturtle()`

`turtle.st()`

Make the turtle visible.

```
>>> turtle.showturtle()
```

`turtle.isvisible()`

Return True if the Turtle is shown, False if it's hidden.

```
>>> turtle.hideturtle()
>>> turtle.isvisible()
False
>>> turtle.showturtle()
>>> turtle.isvisible()
True
```

### Appearance

`turtle.shape(name=None)`

**Parameters** *name* – a string which is a valid shapename

Set turtle shape to shape with given *name* or, if name is not given, return name of current shape. Shape with *name* must exist in the TurtleScreen's shape dictionary. Initially there are the following polygon shapes: "arrow", "turtle", "circle", "square", "triangle", "classic". To learn about how to deal with shapes see Screen method `register_shape()`.

```
>>> turtle.shape()
'classic'
>>> turtle.shape("turtle")
>>> turtle.shape()
'turtle'
```

`turtle.resizemode(rmode=None)`

**Parameters** *rmode* – one of the strings "auto", "user", "noresize"

Set `resizemode` to one of the values: "auto", "user", "noresize". If *rmode* is not given, return current `resizemode`. Different `resizemodes` have the following effects:

- "auto": adapts the appearance of the turtle corresponding to the value of `pensize`.
- "user": adapts the appearance of the turtle according to the values of `stretchfactor` and `outlinewidth` (outline), which are set by `shapessize()`.
- "noresize": no adaption of the turtle's appearance takes place.

`resizemode("user")` is called by `shapessize()` when used with arguments.

```
>>> turtle.resizemode()
'noresize'
>>> turtle.resizemode("auto")
>>> turtle.resizemode()
'auto'
```

`turtle.shapesize(stretch_wid=None, stretch_len=None, outline=None)`

`turtle.turtlesize(stretch_wid=None, stretch_len=None, outline=None)`

**Parameters**

- **stretch\_wid** – positive number
- **stretch\_len** – positive number
- **outline** – positive number

Return or set the pen's attributes *x/y*-stretchfactors and/or outline. Set `resizemode` to "user". If and only if `resizemode` is set to "user", the turtle will be displayed stretched according to its stretchfactors: *stretch\_wid* is stretchfactor perpendicular to its orientation, *stretch\_len* is stretchfactor in direction of its orientation, *outline* determines the width of the shapes's outline.

```
>>> turtle.shapesize()
(1, 1, 1)
>>> turtle.resizemode("user")
>>> turtle.shapesize(5, 5, 12)
>>> turtle.shapesize()
(5, 5, 12)
>>> turtle.shapesize(outline=8)
>>> turtle.shapesize()
(5, 5, 8)
```

`turtle.tilt` (*angle*)

**Parameters** *angle* – a number

Rotate the turtleshape by *angle* from its current tilt-angle, but do *not* change the turtle's heading (direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.tilt(30)
>>> turtle.fd(50)
>>> turtle.tilt(30)
>>> turtle.fd(50)
```

`turtle.settiltangle` (*angle*)

**Parameters** *angle* – a number

Rotate the turtleshape to point in the direction specified by *angle*, regardless of its current tilt-angle. *Do not* change the turtle's heading (direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.settiltangle(45)
>>> turtle.fd(50)
>>> turtle.settiltangle(-45)
>>> turtle.fd(50)
```

`turtle.tiltangle` ()

Return the current tilt-angle, i.e. the angle between the orientation of the turtleshape and the heading of the turtle (its direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.tilt(45)
>>> turtle.tiltangle()
45.0
```

## Using events

`turtle.onclick` (*fun*, *btn=1*, *add=None*)

**Parameters**

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-click events on this turtle. If *fun* is None, existing bindings are removed. Example for the anonymous turtle, i.e. the procedural way:

```

>>> def turn(x, y):
...     left(180)
...
>>> onclick(turn) # Now clicking into the turtle will turn it.
>>> onclick(None) # event-binding will be removed

```

`turtle.onrelease` (*fun*, *btn=1*, *add=None*)

#### Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-button-release events on this turtle. If *fun* is None, existing bindings are removed.

```

>>> class MyTurtle(Turtle):
...     def glow(self, x, y):
...         self.fillcolor("red")
...     def unglow(self, x, y):
...         self.fillcolor("")
...
>>> turtle = MyTurtle()
>>> turtle.onclick(turtle.glow) # clicking on turtle turns fillcolor red,
>>> turtle.onrelease(turtle.unglow) # releasing turns it to transparent.

```

`turtle.ondrag` (*fun*, *btn=1*, *add=None*)

#### Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-move events on this turtle. If *fun* is None, existing bindings are removed.

Remark: Every sequence of mouse-move-events on a turtle is preceded by a mouse-click event on that turtle.

```
>>> turtle.ondrag(turtle.goto)
```

Subsequently, clicking and dragging the Turtle will move it across the screen thereby producing handdrawings (if pen is down).

`turtle.mainloop` ()

`turtle.done` ()

Starts event loop - calling Tkinter's mainloop function. Must be the last statement in a turtle graphics program.

```
>>> turtle.mainloop()
```

## Special Turtle methods

`turtle.begin_poly()`

Start recording the vertices of a polygon. Current turtle position is first vertex of polygon.

`turtle.end_poly()`

Stop recording the vertices of a polygon. Current turtle position is last vertex of polygon. This will be connected with the first vertex.

`turtle.get_poly()`

Return the last recorded polygon.

```
>>> turtle.home()
>>> turtle.begin_poly()
>>> turtle.fd(100)
>>> turtle.left(20)
>>> turtle.fd(30)
>>> turtle.left(60)
>>> turtle.fd(50)
>>> turtle.end_poly()
>>> p = turtle.get_poly()
>>> register_shape("myFavouriteShape", p)
```

`turtle.clone()`

Create and return a clone of the turtle with same position, heading and turtle properties.

```
>>> mick = Turtle()
>>> joe = mick.clone()
```

`turtle.getturtle()`

`turtle.getpen()`

Return the Turtle object itself. Only reasonable use: as a function to return the “anonymous turtle”:

```
>>> pet = getturtle()
>>> pet.fd(50)
>>> pet
<turtle.Turtle object at 0x...>
```

`turtle.getscreen()`

Return the `TurtleScreen` object the turtle is drawing on. `TurtleScreen` methods can then be called for that object.

```
>>> ts = turtle.getscreen()
>>> ts
<turtle._Screen object at 0x...>
>>> ts.bgcolor("pink")
```

`turtle.setundobuffer(size)`

**Parameters** `size` – an integer or `None`

Set or disable undobuffer. If `size` is an integer an empty undobuffer of given size is installed. `size` gives the maximum number of turtle actions that can be undone by the `undo()` method/function. If `size` is `None`, the undobuffer is disabled.

```
>>> turtle.setundobuffer(42)
```

`turtle.undobufferentries()`

Return number of entries in the undobuffer.

```
>>> while undobufferentries():
...     undo()
```

`turtle.tracer(flag=None, delay=None)`

A replica of the corresponding TurtleScreen method. Deprecated since version 2.6.

`turtle.window_width()`

`turtle.window_height()`

Both are replicas of the corresponding TurtleScreen methods. Deprecated since version 2.6.

### Excursus about the use of compound shapes

To use compound turtle shapes, which consist of several polygons of different color, you must use the helper class `Shape` explicitly as described below:

1. Create an empty `Shape` object of type “compound”.
2. Add as many components to this object as desired, using the `addcomponent()` method.

For example:

```
>>> s = Shape("compound")
>>> poly1 = ((0,0), (10,-5), (0,10), (-10,-5))
>>> s.addcomponent(poly1, "red", "blue")
>>> poly2 = ((0,0), (10,-5), (-10,-5))
>>> s.addcomponent(poly2, "blue", "red")
```

3. Now add the `Shape` to the Screen’s shapelist and use it:

```
>>> register_shape("myshape", s)
>>> shape("myshape")
```

---

**Note:** The `Shape` class is used internally by the `register_shape()` method in different ways. The application programmer has to deal with the `Shape` class *only* when using compound shapes like shown above!

---

## 24.5.4 Methods of TurtleScreen/Screen and corresponding functions

Most of the examples in this section refer to a `TurtleScreen` instance called `screen`.

### Window control

`turtle.bgcolor(*args)`

**Parameters** `args` – a color string or three numbers in the range 0..`colormode` or a 3-tuple of such numbers

Set or return background color of the `TurtleScreen`.

```
>>> screen.bgcolor("orange")
>>> screen.bgcolor()
'orange'
>>> screen.bgcolor("#800080")
```

```
>>> screen.bgcolor()  
(128, 0, 128)
```

`turtle.bgpic` (*picname=None*)

**Parameters** *picname* – a string, name of a gif-file or "nopic", or None

Set background image or return name of current backgroundimage. If *picname* is a filename, set the corresponding image as background. If *picname* is "nopic", delete background image, if present. If *picname* is None, return the filename of the current backgroundimage.

```
>>> screen.bgpic()  
'nopic'  
>>> screen.bgpic("landscape.gif")  
>>> screen.bgpic()  
"landscape.gif"
```

`turtle.clear` ()

`turtle.clearscreen` ()

Delete all drawings and all turtles from the TurtleScreen. Reset the now empty TurtleScreen to its initial state: white background, no background image, no event bindings and tracing on.

---

**Note:** This TurtleScreen method is available as a global function only under the name `clearscreen`. The global function `clear` is another one derived from the Turtle method `clear`.

---

`turtle.reset` ()

`turtle.resetscreen` ()

Reset all Turtles on the Screen to their initial state.

---

**Note:** This TurtleScreen method is available as a global function only under the name `resetscreen`. The global function `reset` is another one derived from the Turtle method `reset`.

---

`turtle.screensize` (*canvwidth=None, canvheight=None, bg=None*)

**Parameters**

- **canvwidth** – positive integer, new width of canvas in pixels
- **canvheight** – positive integer, new height of canvas in pixels
- **bg** – colorstring or color-tuple, new background color

If no arguments are given, return current (canvaswidth, canvasheight). Else resize the canvas the turtles are drawing on. Do not alter the drawing window. To observe hidden parts of the canvas, use the scrollbars. With this method, one can make visible those parts of a drawing which were outside the canvas before.

```
>>> screen.screensize()  
(400, 300)  
>>> screen.screensize(2000,1500)  
>>> screen.screensize()  
(2000, 1500)
```

e.g. to search for an erroneously escaped turtle ;-)

`turtle.setworldcoordinates` (*llx, lly, urx, ury*)

**Parameters**

- **llx** – a number, x-coordinate of lower left corner of canvas
- **lly** – a number, y-coordinate of lower left corner of canvas
- **urx** – a number, x-coordinate of upper right corner of canvas
- **ury** – a number, y-coordinate of upper right corner of canvas

Set up user-defined coordinate system and switch to mode “world” if necessary. This performs a `screen.reset()`. If mode “world” is already active, all drawings are redrawn according to the new coordinates.

**ATTENTION:** in user-defined coordinate systems angles may appear distorted.

```
>>> screen.reset()
>>> screen.setworldcoordinates(-50,-7.5,50,7.5)
>>> for _ in range(72):
...     left(10)
...
>>> for _ in range(8):
...     left(45); fd(2)    # a regular octagon
```

## Animation control

`turtle.delay(delay=None)`

**Parameters** `delay` – positive integer

Set or return the drawing *delay* in milliseconds. (This is approximately the time interval between two consecutive canvas updates.) The longer the drawing delay, the slower the animation.

Optional argument:

```
>>> screen.delay()
10
>>> screen.delay(5)
>>> screen.delay()
5
```

`turtle.tracer(n=None, delay=None)`

**Parameters**

- **n** – nonnegative integer
- **delay** – nonnegative integer

Turn turtle animation on/off and set delay for update drawings. If *n* is given, only each *n*-th regular screen update is really performed. (Can be used to accelerate the drawing of complex graphics.) Second argument sets delay value (see `delay()`).

```
>>> screen.tracer(8, 25)
>>> dist = 2
>>> for i in range(200):
...     fd(dist)
...     rt(90)
...     dist += 2
```

`turtle.update()`

Perform a TurtleScreen update. To be used when tracer is turned off.

See also the RawTurtle/Turtle method `speed()`.

## Using screen events

`turtle.listen(xdummy=None, ydummy=None)`

Set focus on TurtleScreen (in order to collect key-events). Dummy arguments are provided in order to be able to pass `listen()` to the `onclick` method.

`turtle.onkey(fun, key)`

### Parameters

- **fun** – a function with no arguments or `None`
- **key** – a string: key (e.g. “a”) or key-symbol (e.g. “space”)

Bind *fun* to key-release event of key. If *fun* is `None`, event bindings are removed. Remark: in order to be able to register key-events, TurtleScreen must have the focus. (See method `listen()`.)

```
>>> def f():
...     fd(50)
...     lt(60)
...
>>> screen.onkey(f, "Up")
>>> screen.listen()
```

`turtle.onclick(fun, btn=1, add=None)`

`turtle.onscreenclick(fun, btn=1, add=None)`

### Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – `True` or `False` – if `True`, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-click events on this screen. If *fun* is `None`, existing bindings are removed.

Example for a TurtleScreen instance named `screen` and a Turtle instance named `turtle`:

```
>>> screen.onclick(turtle.goto) # Subsequently clicking into the TurtleScreen will
>>>                               # make the turtle move to the clicked point.
>>> screen.onclick(None)       # remove event binding again
```

---

**Note:** This TurtleScreen method is available as a global function only under the name `onscreenclick`. The global function `onclick` is another one derived from the Turtle method `onclick`.

---

`turtle.ontimer(fun, t=0)`

### Parameters

- **fun** – a function with no arguments
- **t** – a number  $\geq 0$

Install a timer that calls *fun* after *t* milliseconds.

```
>>> running = True
>>> def f():
...     if running:
...         fd(50)
...         lt(60)
...         screen.ontimer(f, 250)
>>> f()    ### makes the turtle march around
>>> running = False
```

## Settings and special methods

`turtle.mode` (*mode=None*)

**Parameters** `mode` – one of the strings “standard”, “logo” or “world”

Set turtle mode (“standard”, “logo” or “world”) and perform reset. If mode is not given, current mode is returned.

Mode “standard” is compatible with old `turtle`. Mode “logo” is compatible with most Logo turtle graphics. Mode “world” uses user-defined “world coordinates”. **Attention:** in this mode angles appear distorted if *x/y* unit-ratio doesn’t equal 1.

Mode	Initial turtle heading	positive angles
“standard”	to the right (east)	counterclockwise
“logo”	upward (north)	clockwise

```
>>> mode("logo")    # resets turtle heading to north
>>> mode()
'logo'
```

`turtle.colormode` (*cmode=None*)

**Parameters** `cmode` – one of the values 1.0 or 255

Return the colormode or set it to 1.0 or 255. Subsequently *r*, *g*, *b* values of color triples have to be in the range 0..*cmode*.

```
>>> screen.colormode(1)
>>> turtle.pencolor(240, 160, 80)
Traceback (most recent call last):
...
TurtleGraphicsError: bad color sequence: (240, 160, 80)
>>> screen.colormode()
1.0
>>> screen.colormode(255)
>>> screen.colormode()
255
>>> turtle.pencolor(240,160,80)
```

`turtle.getcanvas` ()

Return the Canvas of this TurtleScreen. Useful for insiders who know what to do with a Tkinter Canvas.

```
>>> cv = screen.getcanvas()
>>> cv
<turtle.ScrolledCanvas instance at 0x...>
```

`turtle.getshapes()`

Return a list of names of all currently available turtle shapes.

```
>>> screen.getshapes()
['arrow', 'blank', 'circle', ..., 'turtle']
```

`turtle.register_shape(name, shape=None)`

`turtle.addshape(name, shape=None)`

There are three different ways to call this function:

1. *name* is the name of a gif-file and *shape* is None: Install the corresponding image shape.

```
>>> screen.register_shape("turtle.gif")
```

---

**Note:** Image shapes *do not* rotate when turning the turtle, so they do not display the heading of the turtle!

---

2. *name* is an arbitrary string and *shape* is a tuple of pairs of coordinates: Install the corresponding polygon shape.

```
>>> screen.register_shape("triangle", ((5,-3), (0,5), (-5,-3)))
```

3. *name* is an arbitrary string and *shape* is a (compound) `Shape` object: Install the corresponding compound shape.

Add a turtle shape to TurtleScreen's shapelist. Only thusly registered shapes can be used by issuing the command `shape(shapename)`.

`turtle.turtles()`

Return the list of turtles on the screen.

```
>>> for turtle in screen.turtles():
...     turtle.color("red")
```

`turtle.window_height()`

Return the height of the turtle window.

```
>>> screen.window_height()
480
```

`turtle.window_width()`

Return the width of the turtle window.

```
>>> screen.window_width()
640
```

### Methods specific to Screen, not inherited from TurtleScreen

`turtle.bye()`

Shut the turtlegraphics window.

`turtle.exitonclick()`

Bind `bye()` method to mouse clicks on the Screen.

If the value “using\_IDLE” in the configuration dictionary is `False` (default value), also enter `mainloop`. Remark: If IDLE with the `-n` switch (no subprocess) is used, this value should be set to `True` in `turtle.cfg`. In this case IDLE’s own `mainloop` is active also for the client script.

```
turtle.setup (width=_CFG["width"],      height=_CFG["height"],      startx=_CFG["letright"],
              starty=_CFG["topbottom"])
```

Set the size and position of the main window. Default values of arguments are stored in the configuration dictionary and can be changed via a `turtle.cfg` file.

#### Parameters

- **width** – if an integer, a size in pixels, if a float, a fraction of the screen; default is 50% of screen
- **height** – if an integer, the height in pixels, if a float, a fraction of the screen; default is 75% of screen
- **startx** – if positive, starting position in pixels from the left edge of the screen, if negative from the right edge, if `None`, center window horizontally
- **starty** – if positive, starting position in pixels from the top edge of the screen, if negative from the bottom edge, if `None`, center window vertically

```
>>> screen.setup (width=200, height=200, startx=0, starty=0)
>>>                # sets window to 200x200 pixels, in upper left of screen
>>> screen.setup (width=.75, height=0.5, startx=None, starty=None)
>>>                # sets window to 75% of screen by 50% of screen and centers
```

```
turtle.title (titlestring)
```

**Parameters** `titlestring` – a string that is shown in the titlebar of the turtle graphics window

Set title of turtle window to `titlestring`.

```
>>> screen.title("Welcome to the turtle zoo!")
```

## 24.5.5 The public classes of the module `turtle`

```
class turtle.RawTurtle (canvas)
```

```
class turtle.RawPen (canvas)
```

**Parameters** `canvas` – a `Tkinter.Canvas`, a `ScrolledCanvas` or a `TurtleScreen`

Create a turtle. The turtle has all methods described above as “methods of Turtle/RawTurtle”.

```
class turtle.Turtle
```

Subclass of `RawTurtle`, has the same interface but draws on a default `Screen` object created automatically when needed for the first time.

```
class turtle.TurtleScreen (cv)
```

**Parameters** `cv` – a `Tkinter.Canvas`

Provides screen oriented methods like `setbg()` etc. that are described above.

```
class turtle.Screen
```

Subclass of `TurtleScreen`, with *four methods added*.

```
class turtle.ScrolledCanvas (master)
```

**Parameters** `master` – some `Tkinter` widget to contain the `ScrolledCanvas`, i.e. a `Tkinter-canvas` with scrollbars added

Used by class `Screen`, which thus automatically provides a `ScrolledCanvas` as playground for the turtles.

**class** `turtle.Shape` (*type\_*, *data*)

**Parameters** *type\_* – one of the strings “polygon”, “image”, “compound”

Data structure modeling shapes. The pair (*type\_*, *data*) must follow this specification:

<i>type_</i>	<i>data</i>
“polygon”	a polygon-tuple, i.e. a tuple of pairs of coordinates
“image”	an image (in this form only used internally!)
“compound”	None (a compound shape has to be constructed using the <code>addcomponent()</code> method)

**addcomponent** (*poly*, *fill*, *outline=None*)

**Parameters**

- **poly** – a polygon, i.e. a tuple of pairs of numbers
- **fill** – a color the *poly* will be filled with
- **outline** – a color for the *poly*’s outline (if given)

Example:

```
>>> poly = ((0,0), (10,-5), (0,10), (-10,-5))
>>> s = Shape("compound")
>>> s.addcomponent(poly, "red", "blue")
>>> # ... add more components and then use register_shape()
```

See *Excursus about the use of compound shapes*.

**class** `turtle.Vec2D` (*x*, *y*)

A two-dimensional vector class, used as a helper class for implementing turtle graphics. May be useful for turtle graphics programs too. Derived from tuple, so a vector is a tuple!

Provides (for *a*, *b* vectors, *k* number):

- *a* + *b* vector addition
- *a* - *b* vector subtraction
- *a* \* *b* inner product
- *k* \* *a* and *a* \* *k* multiplication with scalar
- `abs(a)` absolute value of *a*
- `a.rotate(angle)` rotation

## 24.5.6 Help and configuration

### How to use help

The public methods of the `Screen` and `Turtle` classes are documented extensively via docstrings. So these can be used as online-help via the Python help facilities:

- When using IDLE, tooltips show the signatures and first lines of the docstrings of typed in function-/method calls.
- Calling `help()` on methods or functions displays the docstrings:

```
>>> help(Screen.bgcolor)
Help on method bgcolor in module turtle:

bgcolor(self, *args) unbound turtle.Screen method
    Set or return backgroundcolor of the TurtleScreen.

    Arguments (if given): a color string or three numbers
    in the range 0..colormode or a 3-tuple of such numbers.

>>> screen.bgcolor("orange")
>>> screen.bgcolor()
"orange"
>>> screen.bgcolor(0.5,0,0.5)
>>> screen.bgcolor()
"#800080"
```

```
>>> help(Turtle.penup)
Help on method penup in module turtle:

penup(self) unbound turtle.Turtle method
    Pull the pen up -- no drawing when moving.

    Aliases: penup | pu | up

    No argument

>>> turtle.penup()
```

- The docstrings of the functions which are derived from methods have a modified form:

```
>>> help(bgcolor)
Help on function bgcolor in module turtle:

bgcolor(*args)
    Set or return backgroundcolor of the TurtleScreen.

    Arguments (if given): a color string or three numbers
    in the range 0..colormode or a 3-tuple of such numbers.

    Example::

>>> bgcolor("orange")
>>> bgcolor()
"orange"
>>> bgcolor(0.5,0,0.5)
>>> bgcolor()
"#800080"

>>> help(penup)
Help on function penup in module turtle:

penup()
    Pull the pen up -- no drawing when moving.
```

Aliases: `penup` | `pu` | `up`

No argument

Example:

```
>>> penup()
```

These modified docstrings are created automatically together with the function definitions that are derived from the methods at import time.

### Translation of docstrings into different languages

There is a utility to create a dictionary the keys of which are the method names and the values of which are the docstrings of the public methods of the classes `Screen` and `Turtle`.

```
turtle.write_docstringdict(filename="turtle_docstringdict")
```

**Parameters** `filename` – a string, used as filename

Create and write docstring-dictionary to a Python script with the given filename. This function has to be called explicitly (it is not used by the turtle graphics classes). The docstring dictionary will be written to the Python script `filename.py`. It is intended to serve as a template for translation of the docstrings into different languages.

If you (or your students) want to use `turtle` with online help in your native language, you have to translate the docstrings and save the resulting file as e.g. `turtle_docstringdict_german.py`.

If you have an appropriate entry in your `turtle.cfg` file this dictionary will be read in at import time and will replace the original English docstrings.

At the time of this writing there are docstring dictionaries in German and in Italian. (Requests please to [glingl@aon.at](mailto:glingl@aon.at).)

### How to configure Screen and Turtles

The built-in default configuration mimics the appearance and behaviour of the old turtle module in order to retain best possible compatibility with it.

If you want to use a different configuration which better reflects the features of this module or which better fits to your needs, e.g. for use in a classroom, you can prepare a configuration file `turtle.cfg` which will be read at import time and modify the configuration according to its settings.

The built in configuration would correspond to the following `turtle.cfg`:

```
width = 0.5
height = 0.75
letright = None
topbottom = None
canvwidth = 400
canvheight = 300
mode = standard
colormode = 1.0
delay = 10
undobuffersize = 1000
shape = classic
pencolor = black
fillcolor = black
resizemode = noresize
visible = True
```

```
language = english
exampleturtle = turtle
examplescreen = screen
title = Python Turtle Graphics
using_IDLE = False
```

Short explanation of selected entries:

- The first four lines correspond to the arguments of the `Screen.setup()` method.
- Line 5 and 6 correspond to the arguments of the method `Screen.screensize()`.
- *shape* can be any of the built-in shapes, e.g: arrow, turtle, etc. For more info try `help(shape)`.
- If you want to use no fillcolor (i.e. make the turtle transparent), you have to write `fillcolor = ""` (but all nonempty strings must not have quotes in the `cfg`-file).
- If you want to reflect the turtle its state, you have to use `resizemode = auto`.
- If you set e.g. `language = italian` the docstringdict `turtle_docstringdict_italian.py` will be loaded at import time (if present on the import path, e.g. in the same directory as `turtle`).
- The entries `exampleturtle` and `examplescreen` define the names of these objects as they occur in the docstrings. The transformation of method-docstrings to function-docstrings will delete these names from the docstrings.
- *using\_IDLE*: Set this to `True` if you regularly work with IDLE and its `-n` switch (“no subprocess”). This will prevent `exitonclick()` to enter the mainloop.

There can be a `turtle.cfg` file in the directory where `turtle` is stored and an additional one in the current working directory. The latter will override the settings of the first one.

The `Demo/turtle` directory contains a `turtle.cfg` file. You can study it as an example and see its effects when running the demos (preferably not from within the demo-viewer).

## 24.5.7 Demo scripts

There is a set of demo scripts in the `turtledemo` directory located in the `Demo/turtle` directory in the source distribution.

It contains:

- a set of 15 demo scripts demonstrating different features of the new module `turtle`
- a demo viewer `turtleDemo.py` which can be used to view the sourcecode of the scripts and run them at the same time. 14 of the examples can be accessed via the Examples menu; all of them can also be run standalone.
- The example `turtledemo_two_c canvases.py` demonstrates the simultaneous use of two canvases with the `turtle` module. Therefore it only can be run standalone.
- There is a `turtle.cfg` file in this directory, which also serves as an example for how to write and use such files.

The demoscripts are:

Name	Description	Features
byt- edesign	complex classical turtlegraphics pattern	<code>tracer()</code> , <code>delay</code> , <code>update()</code>
chaos	graphs Verhulst dynamics, shows that computer's computations can generate results sometimes against the common sense expectations	world coordinates
clock	analog clock showing time of your computer	turtles as clock's hands, <code>ontimer</code>
col- ormixer	experiment with r, g, b	<code>ondrag()</code>
fractal- curves	Hilbert & Koch curves	recursion
linden- mayer	ethnomathematics (indian kolams)	L-System
mini- mal_hanoi	Towers of Hanoi	Rectangular Turtles as Hanoi discs (shape, shapysize)
paint	super minimalistic drawing program	<code>onclick()</code>
peace	elementary	turtle: appearance and animation
penrose	aperiodic tiling with kites and darts	<code>stamp()</code>
planet_and_sun	simulation of gravitational system	compound shapes, <code>Vec2D</code>
tree	a (graphical) breadth first tree (using generators)	<code>clone()</code>
wikipedia	a pattern from the wikipedia article on turtle graphics	<code>clone()</code> , <code>undo()</code>
yingyang	another elementary example	<code>circle()</code>

Have fun!

## 24.6 IDLE

IDLE is the Python IDE built with the `tkinter` GUI toolkit.

IDLE has the following features:

- coded in 100% pure Python, using the `tkinter` GUI toolkit
- cross-platform: works on Windows and Unix
- multi-window text editor with multiple undo, Python colorizing and many other features, e.g. smart indent and call tips
- Python shell window (a.k.a. interactive interpreter)
- debugger (not complete, but you can set breakpoints, view and step)

### 24.6.1 Menus

#### File menu

**New window** create a new editing window

**Open...** open an existing file

**Open module...** open an existing module (searches `sys.path`)

**Class browser** show classes and methods in current file

**Path browser** show `sys.path` directories, modules, classes and methods

**Save** save current window to the associated file (unsaved windows have a \* before and after the window title)

**Save As...** save current window to new file, which becomes the associated file

**Save Copy As...** save current window to different file without changing the associated file

**Close** close current window (asks to save if unsaved)

**Exit** close all windows and quit IDLE (asks to save if unsaved)

## Edit menu

**Undo** Undo last change to current window (max 1000 changes)

**Redo** Redo last undone change to current window

**Cut** Copy selection into system-wide clipboard; then delete selection

**Copy** Copy selection into system-wide clipboard

**Paste** Insert system-wide clipboard into window

**Select All** Select the entire contents of the edit buffer

**Find...** Open a search dialog box with many options

**Find again** Repeat last search

**Find selection** Search for the string in the selection

**Find in Files...** Open a search dialog box for searching files

**Replace...** Open a search-and-replace dialog box

**Go to line** Ask for a line number and show that line

**Indent region** Shift selected lines right 4 spaces

**Dedent region** Shift selected lines left 4 spaces

**Comment out region** Insert ## in front of selected lines

**Uncomment region** Remove leading # or ## from selected lines

**Tabify region** Turns *leading* stretches of spaces into tabs

**Untabify region** Turn *all* tabs into the right number of spaces

**Expand word** Expand the word you have typed to match another word in the same buffer; repeat to get a different expansion

**Format Paragraph** Reformat the current blank-line-separated paragraph

**Import module** Import or reload the current module

**Run script** Execute the current file in the `__main__` namespace

## Windows menu

**Zoom Height** toggles the window between normal size (24x80) and maximum height.

The rest of this menu lists the names of all open windows; select one to bring it to the foreground (deiconifying it if necessary).

### Debug menu (in the Python Shell window only)

**Go to file/line** look around the insert point for a filename and linenumber, open the file, and show the line.

**Open stack viewer** show the stack traceback of the last exception

**Debugger toggle** Run commands in the shell under the debugger

**JIT Stack viewer toggle** Open stack viewer on traceback

## 24.6.2 Basic editing and navigation

- `Backspace` deletes to the left; `Del` deletes to the right
- `Arrow keys` and `Page Up/Page Down` to move around
- `Home/End` go to begin/end of line
- `C-Home/C-End` go to begin/end of file
- Some **Emacs** bindings may also work, including `C-B`, `C-P`, `C-A`, `C-E`, `C-D`, `C-L`

### Automatic indentation

After a block-opening statement, the next line is indented by 4 spaces (in the Python Shell window by one tab). After certain keywords (`break`, `return` etc.) the next line is dedented. In leading indentation, `Backspace` deletes up to 4 spaces if they are there. `Tab` inserts 1-4 spaces (in the Python Shell window one tab). See also the `indent/dedent` region commands in the edit menu.

### Python Shell window

- `C-C` interrupts executing command
- `C-D` sends end-of-file; closes window if typed at a `>>>` prompt
- `Alt-p` retrieves previous command matching what you have typed
- `Alt-n` retrieves next
- `Return` while on any previous command retrieves that command
- `Alt-/` (Expand word) is also useful here

## 24.6.3 Syntax colors

The coloring is applied in a background “thread,” so you may occasionally see uncolored text. To change the color scheme, edit the `[Colors]` section in `config.txt`.

### Python syntax colors:

**Keywords** orange

**Strings** green

**Comments** red

**Definitions** blue

### Shell colors:

**Console output** brown

**stdout** blue

**stderr** dark green

**stdin** black

## 24.6.4 Startup

Upon startup with the `-s` option, IDLE will execute the file referenced by the environment variables `IDLESTARTUP` or `PYTHONSTARTUP`. Idle first checks for `IDLESTARTUP`; if `IDLESTARTUP` is present the file referenced is run. If `IDLESTARTUP` is not present, Idle checks for `PYTHONSTARTUP`. Files referenced by these environment variables are convenient places to store functions that are used frequently from the Idle shell, or for executing import statements to import common modules.

In addition, Tk also loads a startup file if it is present. Note that the Tk file is loaded unconditionally. This additional file is `.Idle.py` and is looked for in the user's home directory. Statements in this file will be executed in the Tk namespace, so this file is not useful for importing functions to be used from Idle's Python shell.

### Command line usage

```
idle.py [-c command] [-d] [-e] [-s] [-t title] [arg] ...
```

```
-c command  run this command
-d          enable debugger
-e          edit mode; arguments are files to be edited
-s          run $IDLESTARTUP or $PYTHONSTARTUP first
-t title    set title of shell window
```

If there are arguments:

1. If `-e` is used, arguments are files opened for editing and `sys.argv` reflects the arguments passed to IDLE itself.
2. Otherwise, if `-c` is used, all arguments are placed in `sys.argv[1:..]`, with `sys.argv[0]` set to `'-c'`.
3. Otherwise, if neither `-e` nor `-c` is used, the first argument is a script which is executed with the remaining arguments in `sys.argv[1:..]` and `sys.argv[0]` set to the script name. If the script name is `'-'`, no script is executed but an interactive Python session is started; the arguments are still available in `sys.argv`.

## 24.7 Other Graphical User Interface Packages

Major cross-platform (Windows, Mac OS X, Unix-like) GUI toolkits are available for Python:

**See Also:**

**PyGTK** is a set of bindings for the **GTK** widget set. It provides an object oriented interface that is slightly higher level than the C one. It comes with many more widgets than Tkinter provides, and has good Python-specific reference documentation. There are also bindings to **GNOME**. One well known PyGTK application is **PythonCAD**. An online [tutorial](#) is available.

**PyQt** PyQt is a **sip**-wrapped binding to the Qt toolkit. Qt is an extensive C++ GUI application development framework that is available for Unix, Windows and Mac OS X. **sip** is a tool for generating bindings for C++ libraries as Python classes, and is specifically designed for Python. The *PyQt3* bindings have a book, [GUI Programming](#)

with Python: QT Edition by Boudewijn Rempt. The *PyQt4* bindings also have a book, *Rapid GUI Programming with Python and Qt*, by Mark Summerfield.

**wxPython** wxPython is a cross-platform GUI toolkit for Python that is built around the popular *wxWidgets* (formerly *wxWindows*) C++ toolkit. It provides a native look and feel for applications on Windows, Mac OS X, and Unix systems by using each platform's native widgets where ever possible, (GTK+ on Unix-like systems). In addition to an extensive set of widgets, wxPython provides classes for online documentation and context sensitive help, printing, HTML viewing, low-level device context drawing, drag and drop, system clipboard access, an XML-based resource format and more, including an ever growing library of user-contributed modules. wxPython has a book, *wxPython in Action*, by Noel Rappin and Robin Dunn.

PyGTK, PyQt, and wxPython, all have a modern look and feel and more widgets than Tkinter. In addition, there are many other GUI toolkits for Python, both cross-platform, and platform-specific. See the [GUI Programming](#) page in the Python Wiki for a much more complete list, and also for links to documents where the different GUI toolkits are compared.

# DEVELOPMENT TOOLS

The modules described in this chapter help you write software. For example, the `pydoc` module takes a module and generates documentation based on the module's contents. The `doctest` and `unittest` modules contains frameworks for writing unit tests that automatically exercise code and verify that the expected output is produced. **2to3** can translate Python 2.x source code into valid Python 3.x code.

The list of modules described in this chapter is:

## 25.1 `pydoc` — Documentation generator and online help system

New in version 2.1. **Source code:** [Lib/pydoc.py](#)

---

The `pydoc` module automatically generates documentation from Python modules. The documentation can be presented as pages of text on the console, served to a Web browser, or saved to HTML files.

The built-in function `help()` invokes the online help system in the interactive interpreter, which uses `pydoc` to generate its documentation as text on the console. The same text documentation can also be viewed from outside the Python interpreter by running **pydoc** as a script at the operating system's command prompt. For example, running

```
pydoc sys
```

at a shell prompt will display documentation on the `sys` module, in a style similar to the manual pages shown by the Unix **man** command. The argument to **pydoc** can be the name of a function, module, or package, or a dotted reference to a class, method, or function within a module or module in a package. If the argument to **pydoc** looks like a path (that is, it contains the path separator for your operating system, such as a slash in Unix), and refers to an existing Python source file, then documentation is produced for that file.

---

**Note:** In order to find objects and their documentation, `pydoc` imports the module(s) to be documented. Therefore, any code on module level will be executed on that occasion. Use an `if __name__ == '__main__':` guard to only execute code when a file is invoked as a script and not just imported.

---

Specifying a `-w` flag before the argument will cause HTML documentation to be written out to a file in the current directory, instead of displaying text on the console.

Specifying a `-k` flag before the argument will search the synopsis lines of all available modules for the keyword given as the argument, again in a manner similar to the Unix **man** command. The synopsis line of a module is the first line of its documentation string.

You can also use **pydoc** to start an HTTP server on the local machine that will serve documentation to visiting Web browsers. **pydoc -p 1234** will start a HTTP server on port 1234, allowing you to browse the documentation

at `http://localhost:1234/` in your preferred Web browser. `pydoc -g` will start the server and additionally bring up a small `Tkinter`-based graphical interface to help you search for documentation pages.

When `pydoc` generates documentation, it uses the current environment and path to locate modules. Thus, invoking `pydoc spam` documents precisely the version of the module you would get if you started the Python interpreter and typed `import spam`.

Module docs for core modules are assumed to reside in `http://docs.python.org/library/`. This can be overridden by setting the

`PYTHONDOCS` environment variable to a different URL or to a local directory containing the Library Reference Manual pages.

## 25.2 doctest — Test interactive Python examples

The `doctest` module searches for pieces of text that look like interactive Python sessions, and then executes those sessions to verify that they work exactly as shown. There are several common ways to use `doctest`:

- To check that a module's docstrings are up-to-date by verifying that all interactive examples still work as documented.
- To perform regression testing by verifying that interactive examples from a test file or a test object work as expected.
- To write tutorial documentation for a package, liberally illustrated with input-output examples. Depending on whether the examples or the expository text are emphasized, this has the flavor of “literate testing” or “executable documentation”.

Here's a complete but small example module:

```
"""
This is the "example" module.

The example module supplies one function, factorial().  For example,

>>> factorial(5)
120
"""

def factorial(n):
    """Return the factorial of n, an exact integer >= 0.

    If the result is small enough to fit in an int, return an int.
    Else return a long.

    >>> [factorial(n) for n in range(6)]
    [1, 1, 2, 6, 24, 120]
    >>> [factorial(long(n)) for n in range(6)]
    [1, 1, 2, 6, 24, 120]
    >>> factorial(30)
    265252859812191058636308480000000L
    >>> factorial(30L)
    265252859812191058636308480000000L
    >>> factorial(-1)
    Traceback (most recent call last):
    ...
```

```
ValueError: n must be >= 0
```

Factorials of floats are OK, but the float must be an exact integer:

```
>>> factorial(30.1)
Traceback (most recent call last):
```

```
...
ValueError: n must be exact integer
>>> factorial(30.0)
265252859812191058636308480000000L
```

It must also not be ridiculously large:

```
>>> factorial(1e100)
Traceback (most recent call last):
```

```
...
OverflowError: n too large
"""
```

```
import math
if not n >= 0:
    raise ValueError("n must be >= 0")
if math.floor(n) != n:
    raise ValueError("n must be exact integer")
if n+1 == n: # catch a value like 1e300
    raise OverflowError("n too large")
result = 1
factor = 2
while factor <= n:
    result *= factor
    factor += 1
return result
```

```
if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

If you run `example.py` directly from the command line, `doctest` works its magic:

```
$ python example.py
$
```

There's no output! That's normal, and it means all the examples worked. Pass `-v` to the script, and `doctest` prints a detailed log of what it's trying, and prints a summary at the end:

```
$ python example.py -v
Trying:
    factorial(5)
Expecting:
    120
ok
Trying:
    [factorial(n) for n in range(6)]
Expecting:
    [1, 1, 2, 6, 24, 120]
ok
Trying:
```

```
[factorial(long(n)) for n in range(6)]
Expecting:
[1, 1, 2, 6, 24, 120]
ok
```

And so on, eventually ending with:

```
Trying:
    factorial(1e100)
Expecting:
Traceback (most recent call last):
    ...
OverflowError: n too large
ok
2 items passed all tests:
  1 tests in __main__
  8 tests in __main__.factorial
9 tests in 2 items.
9 passed and 0 failed.
Test passed.
$
```

That's all you need to know to start making productive use of `doctest`! Jump in. The following sections provide full details. Note that there are many examples of doctests in the standard Python test suite and libraries. Especially useful examples can be found in the standard test file `Lib/test/test_doctest.py`.

### 25.2.1 Simple Usage: Checking Examples in Docstrings

The simplest way to start using `doctest` (but not necessarily the way you'll continue to do it) is to end each module `M` with:

```
if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

`doctest` then examines docstrings in module `M`.

Running the module as a script causes the examples in the docstrings to get executed and verified:

```
python M.py
```

This won't display anything unless an example fails, in which case the failing example(s) and the cause(s) of the failure(s) are printed to `stdout`, and the final line of output is `***Test Failed*** N failures.`, where `N` is the number of examples that failed.

Run it with the `-v` switch instead:

```
python M.py -v
```

and a detailed report of all examples tried is printed to standard output, along with assorted summaries at the end.

You can force verbose mode by passing `verbose=True` to `testmod()`, or prohibit it by passing `verbose=False`. In either of those cases, `sys.argv` is not examined by `testmod()` (so passing `-v` or not has no effect).

Since Python 2.6, there is also a command line shortcut for running `testmod()`. You can instruct the Python interpreter to run the `doctest` module directly from the standard library and pass the module name(s) on the command line:

```
python -m doctest -v example.py
```

This will import `example.py` as a standalone module and run `testmod()` on it. Note that this may not work correctly if the file is part of a package and imports other submodules from that package.

For more information on `testmod()`, see section *Basic API*.

## 25.2.2 Simple Usage: Checking Examples in a Text File

Another simple application of doctest is testing interactive examples in a text file. This can be done with the `testfile()` function:

```
import doctest
doctest.testfile("example.txt")
```

That short script executes and verifies any interactive Python examples contained in the file `example.txt`. The file content is treated as if it were a single giant docstring; the file doesn't need to contain a Python program! For example, perhaps `example.txt` contains this:

```
The ``example`` module
=====
```

```
Using ``factorial``
-----
```

This is an example text file in reStructuredText format. First import `factorial` from the `example` module:

```
>>> from example import factorial
```

Now use it:

```
>>> factorial(6)
120
```

Running `doctest.testfile("example.txt")` then finds the error in this documentation:

```
File "./example.txt", line 14, in example.txt
Failed example:
    factorial(6)
Expected:
    120
Got:
    720
```

As with `testmod()`, `testfile()` won't display anything unless an example fails. If an example does fail, then the failing example(s) and the cause(s) of the failure(s) are printed to stdout, using the same format as `testmod()`.

By default, `testfile()` looks for files in the calling module's directory. See section *Basic API* for a description of the optional arguments that can be used to tell it to look for files in other locations.

Like `testmod()`, `testfile()`'s verbosity can be set with the `-v` command-line switch or with the optional keyword argument *verbose*.

Since Python 2.6, there is also a command line shortcut for running `testfile()`. You can instruct the Python interpreter to run the doctest module directly from the standard library and pass the file name(s) on the command line:

```
python -m doctest -v example.txt
```

Because the file name does not end with `.py`, `doctest` infers that it must be run with `testfile()`, not `testmod()`.

For more information on `testfile()`, see section *Basic API*.

### 25.2.3 How It Works

This section examines in detail how doctest works: which docstrings it looks at, how it finds interactive examples, what execution context it uses, how it handles exceptions, and how option flags can be used to control its behavior. This is the information that you need to know to write doctest examples; for information about actually running doctest on these examples, see the following sections.

#### Which Docstrings Are Examined?

The module docstring, and all function, class and method docstrings are searched. Objects imported into the module are not searched.

In addition, if `M.__test__` exists and “is true”, it must be a dict, and each entry maps a (string) name to a function object, class object, or string. Function and class object docstrings found from `M.__test__` are searched, and strings are treated as if they were docstrings. In output, a key `K` in `M.__test__` appears with name

```
<name of M>.__test__.K
```

Any classes found are recursively searched similarly, to test docstrings in their contained methods and nested classes. Changed in version 2.4: A “private name” concept is deprecated and no longer documented.

#### How are Docstring Examples Recognized?

In most cases a copy-and-paste of an interactive console session works fine, but doctest isn’t trying to do an exact emulation of any specific Python shell.

```
>>> # comments are ignored
>>> x = 12
>>> x
12
>>> if x == 13:
...     print "yes"
... else:
...     print "no"
...     print "NO"
...     print "NO!!!"
...
no
NO
NO!!!
>>>
```

Any expected output must immediately follow the final `'>>> '` or `'... '` line containing the code, and the expected output (if any) extends to the next `'>>> '` or all-whitespace line.

The fine print:

- Expected output cannot contain an all-whitespace line, since such a line is taken to signal the end of expected output. If expected output does contain a blank line, put `<BLANKLINE>` in your doctest example each place a blank line is expected. New in version 2.4: `<BLANKLINE>` was added; there was no way to use expected output containing empty lines in previous versions.

- All hard tab characters are expanded to spaces, using 8-column tab stops. Tabs in output generated by the tested code are not modified. Because any hard tabs in the sample output *are* expanded, this means that if the code output includes hard tabs, the only way the doctest can pass is if the `NORMALIZE_WHITESPACE` option or directive is in effect. Alternatively, the test can be rewritten to capture the output and compare it to an expected value as part of the test. This handling of tabs in the source was arrived at through trial and error, and has proven to be the least error prone way of handling them. It is possible to use a different algorithm for handling tabs by writing a custom `DocTestParser` class. Changed in version 2.4: Expanding tabs to spaces is new; previous versions tried to preserve hard tabs, with confusing results.
- Output to stdout is captured, but not output to stderr (exception tracebacks are captured via a different means).
- If you continue a line via backslashing in an interactive session, or for any other reason use a backslash, you should use a raw docstring, which will preserve your backslashes exactly as you type them:

```
>>> def f(x):
...     r'''Backslashes in a raw docstring: m\n'''
>>> print f.__doc__
Backslashes in a raw docstring: m\n
```

Otherwise, the backslash will be interpreted as part of the string. For example, the `\n` above would be interpreted as a newline character. Alternatively, you can double each backslash in the doctest version (and not use a raw string):

```
>>> def f(x):
...     '''Backslashes in a raw docstring: m\\n'''
>>> print f.__doc__
Backslashes in a raw docstring: m\n
```

- The starting column doesn't matter:

```
>>> assert "Easy!"
>>> import math
>>> math.floor(1.9)
1.0
```

and as many leading whitespace characters are stripped from the expected output as appeared in the initial `'>>>'` line that started the example.

## What's the Execution Context?

By default, each time `doctest` finds a docstring to test, it uses a *shallow copy* of `M`'s globals, so that running tests doesn't change the module's real globals, and so that one test in `M` can't leave behind crumbs that accidentally allow another test to work. This means examples can freely use any names defined at top-level in `M`, and names defined earlier in the docstring being run. Examples cannot see names defined in other docstrings.

You can force use of your own dict as the execution context by passing `globals=your_dict` to `testmod()` or `testfile()` instead.

## What About Exceptions?

No problem, provided that the traceback is the only output produced by the example: just paste in the traceback.<sup>1</sup> Since tracebacks contain details that are likely to change rapidly (for example, exact file paths and line numbers), this is one case where doctest works hard to be flexible in what it accepts.

Simple example:

<sup>1</sup> Examples containing both expected output and an exception are not supported. Trying to guess where one ends and the other begins is too error-prone, and that also makes for a confusing test.

```
>>> [1, 2, 3].remove(42)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: list.remove(x): x not in list
```

That doctest succeeds if `ValueError` is raised, with the `list.remove(x): x not in list` detail as shown.

The expected output for an exception must start with a traceback header, which may be either of the following two lines, indented the same as the first line of the example:

```
Traceback (most recent call last):
Traceback (innermost last):
```

The traceback header is followed by an optional traceback stack, whose contents are ignored by doctest. The traceback stack is typically omitted, or copied verbatim from an interactive session.

The traceback stack is followed by the most interesting part: the line(s) containing the exception type and detail. This is usually the last line of a traceback, but can extend across multiple lines if the exception has a multi-line detail:

```
>>> raise ValueError('multi\n    line\ndetail')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: multi
    line
detail
```

The last three lines (starting with `ValueError`) are compared against the exception's type and detail, and the rest are ignored. Changed in version 2.4: Previous versions were unable to handle multi-line exception details. Best practice is to omit the traceback stack, unless it adds significant documentation value to the example. So the last example is probably better as:

```
>>> raise ValueError('multi\n    line\ndetail')
Traceback (most recent call last):
...
ValueError: multi
    line
detail
```

Note that tracebacks are treated very specially. In particular, in the rewritten example, the use of `...` is independent of doctest's `ELLIPSIS` option. The ellipsis in that example could be left out, or could just as well be three (or three hundred) commas or digits, or an indented transcript of a Monty Python skit.

Some details you should read once, but won't need to remember:

- Doctest can't guess whether your expected output came from an exception traceback or from ordinary printing. So, e.g., an example that expects `ValueError: 42 is prime` will pass whether `ValueError` is actually raised or if the example merely prints that traceback text. In practice, ordinary output rarely begins with a traceback header line, so this doesn't create real problems.
- Each line of the traceback stack (if present) must be indented further than the first line of the example, *or* start with a non-alphanumeric character. The first line following the traceback header indented the same and starting with an alphanumeric is taken to be the start of the exception detail. Of course this does the right thing for genuine tracebacks.
- When the `IGNORE_EXCEPTION_DETAIL` doctest option is specified, everything following the leftmost colon and any module information in the exception name is ignored.
- The interactive shell omits the traceback header line for some `SyntaxErrors`. But doctest uses the traceback header line to distinguish exceptions from non-exceptions. So in the rare case where you need to test a

`SyntaxError` that omits the traceback header, you will need to manually add the traceback header line to your test example.

- For some `SyntaxErrors`, Python displays the character position of the syntax error, using a `^` marker:

```
>>> 1 1
      File "<stdin>", line 1
        1 1
         ^
```

`SyntaxError`: invalid syntax

Since the lines showing the position of the error come before the exception type and detail, they are not checked by doctest. For example, the following test would pass, even though it puts the `^` marker in the wrong location:

```
>>> 1 1
      File "<stdin>", line 1
        1 1
         ^
```

`SyntaxError`: invalid syntax

## Option Flags and Directives

A number of option flags control various aspects of doctest’s behavior. Symbolic names for the flags are supplied as module constants, which can be or’ed together and passed to various functions. The names can also be used in doctest directives (see below).

The first group of options define test semantics, controlling aspects of how doctest decides whether actual output matches an example’s expected output:

### `doctest.DONT_ACCEPT_TRUE_FOR_1`

By default, if an expected output block contains just `1`, an actual output block containing just `1` or just `True` is considered to be a match, and similarly for `0` versus `False`. When `DONT_ACCEPT_TRUE_FOR_1` is specified, neither substitution is allowed. The default behavior caters to that Python changed the return type of many functions from integer to boolean; doctests expecting “little integer” output still work in these cases. This option will probably go away, but not for several years.

### `doctest.DONT_ACCEPT_BLANKLINE`

By default, if an expected output block contains a line containing only the string `<BLANKLINE>`, then that line will match a blank line in the actual output. Because a genuinely blank line delimits the expected output, this is the only way to communicate that a blank line is expected. When `DONT_ACCEPT_BLANKLINE` is specified, this substitution is not allowed.

### `doctest.NORMALIZE_WHITESPACE`

When specified, all sequences of whitespace (blanks and newlines) are treated as equal. Any sequence of whitespace within the expected output will match any sequence of whitespace within the actual output. By default, whitespace must match exactly. `NORMALIZE_WHITESPACE` is especially useful when a line of expected output is very long, and you want to wrap it across multiple lines in your source.

### `doctest.ELLIPSIS`

When specified, an ellipsis marker (`. . .`) in the expected output can match any substring in the actual output. This includes substrings that span line boundaries, and empty substrings, so it’s best to keep usage of this simple. Complicated uses can lead to the same kinds of “oops, it matched too much!” surprises that `.*` is prone to in regular expressions.

### `doctest.IGNORE_EXCEPTION_DETAIL`

When specified, an example that expects an exception passes if an exception of the expected type is raised, even if the exception detail does not match. For example, an example expecting `ValueError: 42` will pass if the actual exception raised is `ValueError: 3*14`, but will fail, e.g., if `TypeError` is raised.

It will also ignore the module name used in Python 3 doctest reports. Hence both these variations will work regardless of whether the test is run under Python 2.7 or Python 3.2 (or later versions):

```
>>> raise CustomError('message')
Traceback (most recent call last):
CustomError: message
```

```
>>> raise CustomError('message')
Traceback (most recent call last):
my_module.CustomError: message
```

Note that `ELLIPSIS` can also be used to ignore the details of the exception message, but such a test may still fail based on whether or not the module details are printed as part of the exception name. Using `IGNORE_EXCEPTION_DETAIL` and the details from Python 2.3 is also the only clear way to write a doctest that doesn't care about the exception detail yet continues to pass under Python 2.3 or earlier (those releases do not support doctest directives and ignore them as irrelevant comments). For example,

```
>>> (1, 2)[3] = 'moo'
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: object doesn't support item assignment
```

passes under Python 2.3 and later Python versions, even though the detail changed in Python 2.4 to say “does not” instead of “doesn't”. Changed in version 2.7: `IGNORE_EXCEPTION_DETAIL` now also ignores any information relating to the module containing the exception under test

### `doctest.SKIP`

When specified, do not run the example at all. This can be useful in contexts where doctest examples serve as both documentation and test cases, and an example should be included for documentation purposes, but should not be checked. E.g., the example's output might be random; or the example might depend on resources which would be unavailable to the test driver.

The SKIP flag can also be used for temporarily “commenting out” examples.

New in version 2.5.

### `doctest.COMPARISON_FLAGS`

A bitmask or'ing together all the comparison flags above.

The second group of options controls how test failures are reported:

### `doctest.REPORT_UDIFF`

When specified, failures that involve multi-line expected and actual outputs are displayed using a unified diff.

### `doctest.REPORT_CDIFF`

When specified, failures that involve multi-line expected and actual outputs will be displayed using a context diff.

### `doctest.REPORT_NDIFF`

When specified, differences are computed by `diff.lib.Differ`, using the same algorithm as the popular `ndiff.py` utility. This is the only method that marks differences within lines as well as across lines. For example, if a line of expected output contains digit 1 where actual output contains letter l, a line is inserted with a caret marking the mismatching column positions.

### `doctest.REPORT_ONLY_FIRST_FAILURE`

When specified, display the first failing example in each doctest, but suppress output for all remaining examples. This will prevent doctest from reporting correct examples that break because of earlier failures; but it might also hide incorrect examples that fail independently of the first failure. When `REPORT_ONLY_FIRST_FAILURE`

is specified, the remaining examples are still run, and still count towards the total number of failures reported; only the output is suppressed.

#### doctest .REPORTING\_FLAGS

A bitmask or'ing together all the reporting flags above.

“Doctest directives” may be used to modify the option flags for individual examples. Doctest directives are expressed as a special Python comment following an example’s source code:

```
directive          ::=  "#" "doctest:" directive_options
directive_options  ::=  directive_option ("," directive_option)\*
directive_option   ::=  on_or_off directive_option_name
on_or_off          ::=  "+" \| "-"
directive_option_name ::=  "DONT_ACCEPT_BLANKLINE" \| "NORMALIZE_WHITESPACE" \| ...
```

Whitespace is not allowed between the + or – and the directive option name. The directive option name can be any of the option flag names explained above.

An example’s doctest directives modify doctest’s behavior for that single example. Use + to enable the named behavior, or – to disable it.

For example, this test passes:

```
>>> print range(20)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9,
10, 11, 12, 13, 14, 15, 16, 17, 18, 19]
```

Without the directive it would fail, both because the actual output doesn’t have two blanks before the single-digit list elements, and because the actual output is on a single line. This test also passes, and also requires a directive to do so:

```
>>> print range(20)
[0, 1, ..., 18, 19]
```

Multiple directives can be used on a single physical line, separated by commas:

```
>>> print range(20)
[0, 1, ..., 18, 19]
```

If multiple directive comments are used for a single example, then they are combined:

```
>>> print range(20)
...
[0, 1, ..., 18, 19]
```

As the previous example shows, you can add ... lines to your example containing only directives. This can be useful when an example is too long for a directive to comfortably fit on the same line:

```
>>> print range(5) + range(10,20) + range(30,40) + range(50,60)
...
[0, ..., 4, 10, ..., 19, 30, ..., 39, 50, ..., 59]
```

Note that since all options are disabled by default, and directives apply only to the example they appear in, enabling options (via + in a directive) is usually the only meaningful choice. However, option flags can also be passed to functions that run doctests, establishing different defaults. In such cases, disabling an option via – in a directive can be useful. New in version 2.4: Doctest directives and the associated constants `DONT_ACCEPT_BLANKLINE`, `NORMALIZE_WHITESPACE`, `ELLIPSIS`, `IGNORE_EXCEPTION_DETAIL`, `REPORT_UDIFF`, `REPORT_CDIFF`, `REPORT_NDIFF`, `REPORT_ONLY_FIRST_FAILURE`, `COMPARISON_FLAGS` and `REPORTING_FLAGS` were added. There’s also a way to register new option flag names, although this isn’t useful unless you intend to extend `doctest` internals via subclassing:

`doctest.register_optionflag` (*name*)

Create a new option flag with a given name, and return the new flag's integer value. `register_optionflag()` can be used when subclassing `OutputChecker` or `DocTestRunner` to create new options that are supported by your subclasses. `register_optionflag()` should always be called using the following idiom:

```
MY_FLAG = register_optionflag('MY_FLAG')
```

New in version 2.4.

### Warnings

`doctest` is serious about requiring exact matches in expected output. If even a single character doesn't match, the test fails. This will probably surprise you a few times, as you learn exactly what Python does and doesn't guarantee about output. For example, when printing a dict, Python doesn't guarantee that the key-value pairs will be printed in any particular order, so a test like

```
>>> foo()
{"Hermione": "hippogryph", "Harry": "broomstick"}
```

is vulnerable! One workaround is to do

```
>>> foo() == {"Hermione": "hippogryph", "Harry": "broomstick"}
True
```

instead. Another is to do

```
>>> d = foo().items()
>>> d.sort()
>>> d
[('Harry', 'broomstick'), ('Hermione', 'hippogryph')]
```

There are others, but you get the idea.

Another bad idea is to print things that embed an object address, like

```
>>> id(1.0) # certain to fail some of the time
7948648
>>> class C: pass
>>> C() # the default repr() for instances embeds an address
<__main__.C instance at 0x00AC18F0>
```

The `ELLIPSIS` directive gives a nice approach for the last example:

```
>>> C()
<__main__.C instance at 0x...>
```

Floating-point numbers are also subject to small output variations across platforms, because Python defers to the platform C library for float formatting, and C libraries vary widely in quality here.

```
>>> 1./7 # risky
0.14285714285714285
>>> print 1./7 # safer
0.142857142857
>>> print round(1./7, 6) # much safer
0.142857
```

Numbers of the form  $I/2.***J$  are safe across all platforms, and I often contrive doctest examples to produce numbers of that form:

```
>>> 3./4 # utterly safe
0.75
```

Simple fractions are also easier for people to understand, and that makes for better documentation.

## 25.2.4 Basic API

The functions `testmod()` and `testfile()` provide a simple interface to doctest that should be sufficient for most basic uses. For a less formal introduction to these two functions, see sections *Simple Usage: Checking Examples in Docstrings* and *Simple Usage: Checking Examples in a Text File*.

`doctest.testfile(filename[, module_relative][, name][, package][, globs][, verbose][, report][, optionflags][, extraglobs][, raise_on_error][, parser][, encoding])`

All arguments except `filename` are optional, and should be specified in keyword form.

Test examples in the file named `filename`. Return `(failure_count, test_count)`.

Optional argument `module_relative` specifies how the filename should be interpreted:

- If `module_relative` is `True` (the default), then `filename` specifies an OS-independent module-relative path. By default, this path is relative to the calling module's directory; but if the `package` argument is specified, then it is relative to that package. To ensure OS-independence, `filename` should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If `module_relative` is `False`, then `filename` specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.

Optional argument `name` gives the name of the test; by default, or if `None`, `os.path.basename(filename)` is used.

Optional argument `package` is a Python package or the name of a Python package whose directory should be used as the base directory for a module-relative filename. If no package is specified, then the calling module's directory is used as the base directory for module-relative filenames. It is an error to specify `package` if `module_relative` is `False`.

Optional argument `globs` gives a dict to be used as the globals when executing examples. A new shallow copy of this dict is created for the doctest, so its examples start with a clean slate. By default, or if `None`, a new empty dict is used.

Optional argument `extraglobs` gives a dict merged into the globals used to execute examples. This works like `dict.update()`: if `globs` and `extraglobs` have a common key, the associated value in `extraglobs` appears in the combined dict. By default, or if `None`, no extra globals are used. This is an advanced feature that allows parameterization of doctests. For example, a doctest can be written for a base class, using a generic name for the class, then reused to test any number of subclasses by passing an `extraglobs` dict mapping the generic name to the subclass to be tested.

Optional argument `verbose` prints lots of stuff if true, and prints only failures if false; by default, or if `None`, it's true if and only if `'-v'` is in `sys.argv`.

Optional argument `report` prints a summary at the end when true, else prints nothing at the end. In verbose mode, the summary is detailed, else the summary is very brief (in fact, empty if all tests passed).

Optional argument `optionflags` or `s`'s together option flags. See section *Option Flags and Directives*.

Optional argument `raise_on_error` defaults to false. If true, an exception is raised upon the first failure or unexpected exception in an example. This allows failures to be post-mortem debugged. Default behavior is to continue running examples.

Optional argument `parser` specifies a `DocTestParser` (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., `DocTestParser()`).

Optional argument *encoding* specifies an encoding that should be used to convert the file to unicode. New in version 2.4.Changed in version 2.5: The parameter *encoding* was added.

```
doctest.testmod([m][, name][, globs][, verbose][, report][, optionflags][, extraglobs][,
                raise_on_error][, exclude_empty])
```

All arguments are optional, and all except for *m* should be specified in keyword form.

Test examples in docstrings in functions and classes reachable from module *m* (or module `__main__` if *m* is not supplied or is `None`), starting with `m.__doc__`.

Also test examples reachable from dict `m.__test__`, if it exists and is not `None`. `m.__test__` maps names (strings) to functions, classes and strings; function and class docstrings are searched for examples; strings are searched directly, as if they were docstrings.

Only docstrings attached to objects belonging to module *m* are searched.

Return (failure\_count, test\_count).

Optional argument *name* gives the name of the module; by default, or if `None`, `m.__name__` is used.

Optional argument *exclude\_empty* defaults to `false`. If `true`, objects for which no doctests are found are excluded from consideration. The default is a backward compatibility hack, so that code still using `doctest.master.summarize()` in conjunction with `testmod()` continues to get output for objects with no tests. The *exclude\_empty* argument to the newer `DocTestFinder` constructor defaults to `true`.

Optional arguments *extraglobs*, *verbose*, *report*, *optionflags*, *raise\_on\_error*, and *globs* are the same as for function `testfile()` above, except that *globs* defaults to `m.__dict__`. Changed in version 2.3: The parameter *optionflags* was added.Changed in version 2.4: The parameters *extraglobs*, *raise\_on\_error* and *exclude\_empty* were added.Changed in version 2.5: The optional argument *isprivate*, deprecated in 2.4, was removed.

There's also a function to run the doctests associated with a single object. This function is provided for backward compatibility. There are no plans to deprecate it, but it's rarely useful:

```
doctest.run_docstring_examples(f, globs[, verbose][, name][, compileflags][, optionflags])
```

Test examples associated with object *f*; for example, *f* may be a module, function, or class object.

A shallow copy of dictionary argument *globs* is used for the execution context.

Optional argument *name* is used in failure messages, and defaults to `"NoName"`.

If optional argument *verbose* is `true`, output is generated even if there are no failures. By default, output is generated only in case of an example failure.

Optional argument *compileflags* gives the set of flags that should be used by the Python compiler when running the examples. By default, or if `None`, flags are deduced corresponding to the set of future features found in *globs*.

Optional argument *optionflags* works as for function `testfile()` above.

### 25.2.5 Unittest API

As your collection of doctest'ed modules grows, you'll want a way to run all their doctests systematically. Prior to Python 2.4, `doctest` had a barely documented `Tester` class that supplied a rudimentary way to combine doctests from multiple modules. `Tester` was feeble, and in practice most serious Python testing frameworks build on the `unittest` module, which supplies many flexible ways to combine tests from multiple sources. So, in Python 2.4, `doctest`'s `Tester` class is deprecated, and `doctest` provides two functions that can be used to create `unittest` test suites from modules and text files containing doctests. To integrate with `unittest` test discovery, include a `load_tests()` function in your test module:

```
import unittest
import doctest
```

```
import my_module_with_doctests
```

```
def load_tests(loader, tests, ignore):
    tests.addTests(doctest.DocTestSuite(my_module_with_doctests))
    return tests
```

There are two main functions for creating `unittest.TestSuite` instances from text files and modules with doctests:

```
doctest.DocFileSuite(*paths, [module_relative][, package][, setUp][, tearDown][, globs][, option-
                        flags][, parser][, encoding])
```

Convert doctest tests from one or more text files to a `unittest.TestSuite`.

The returned `unittest.TestSuite` is to be run by the unittest framework and runs the interactive examples in each file. If an example in any file fails, then the synthesized unit test fails, and a `failureException` exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Pass one or more paths (as strings) to text files to be examined.

Options may be provided as keyword arguments:

Optional argument `module_relative` specifies how the filenames in `paths` should be interpreted:

- If `module_relative` is `True` (the default), then each filename in `paths` specifies an OS-independent module-relative path. By default, this path is relative to the calling module's directory; but if the `package` argument is specified, then it is relative to that package. To ensure OS-independence, each filename should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If `module_relative` is `False`, then each filename in `paths` specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.

Optional argument `package` is a Python package or the name of a Python package whose directory should be used as the base directory for module-relative filenames in `paths`. If no package is specified, then the calling module's directory is used as the base directory for module-relative filenames. It is an error to specify `package` if `module_relative` is `False`.

Optional argument `setUp` specifies a set-up function for the test suite. This is called before running the tests in each file. The `setUp` function will be passed a `DocTest` object. The `setUp` function can access the test globals as the `globs` attribute of the test passed.

Optional argument `tearDown` specifies a tear-down function for the test suite. This is called after running the tests in each file. The `tearDown` function will be passed a `DocTest` object. The `setUp` function can access the test globals as the `globs` attribute of the test passed.

Optional argument `globs` is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, `globs` is a new empty dictionary.

Optional argument `optionflags` specifies the default doctest options for the tests, created by oring together individual option flags. See section [Option Flags and Directives](#). See function `set_unittest_reportflags()` below for a better way to set reporting options.

Optional argument `parser` specifies a `DocTestParser` (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., `DocTestParser()`).

Optional argument `encoding` specifies an encoding that should be used to convert the file to unicode. New in version 2.4. Changed in version 2.5: The global `__file__` was added to the globals provided to doctests loaded from a text file using `DocFileSuite()`. Changed in version 2.5: The parameter `encoding` was added.

---

**Note:** Unlike `testmod()` and `DocTestFinder`, this function raises a `ValueError` if `module` contains no docstrings. You can prevent this error by passing a `DocTestFinder` instance as the `test_finder` argument with its `exclude_empty` keyword argument set to `False`:

```
>>> finder = doctest.DocTestFinder(exclude_empty=False)
>>> suite = doctest.DocTestSuite(test_finder=finder)
```

---

`doctest.DocTestSuite` (*[module][, globs][, extraglobs][, test\_finder][, setUp][, tearDown][, checker]*)  
Convert doctest tests for a module to a `unittest.TestSuite`.

The returned `unittest.TestSuite` is to be run by the `unittest` framework and runs each doctest in the module. If any of the doctests fail, then the synthesized unit test fails, and a `failureException` exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Optional argument *module* provides the module to be tested. It can be a module object or a (possibly dotted) module name. If not specified, the module calling this function is used.

Optional argument *globs* is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, *globs* is a new empty dictionary.

Optional argument *extraglobs* specifies an extra set of global variables, which is merged into *globs*. By default, no extra globals are used.

Optional argument *test\_finder* is the `DocTestFinder` object (or a drop-in replacement) that is used to extract doctests from the module.

Optional arguments *setUp*, *tearDown*, and *optionflags* are the same as for function `DocFileSuite()` above. New in version 2.3. Changed in version 2.4: The parameters *globs*, *extraglobs*, *test\_finder*, *setUp*, *tearDown*, and *optionflags* were added; this function now uses the same search technique as `testmod()`.

Under the covers, `DocTestSuite()` creates a `unittest.TestSuite` out of `doctest.DocTestCase` instances, and `DocTestCase` is a subclass of `unittest.TestCase`. `DocTestCase` isn't documented here (it's an internal detail), but studying its code can answer questions about the exact details of `unittest` integration.

Similarly, `DocFileSuite()` creates a `unittest.TestSuite` out of `doctest.DocFileCase` instances, and `DocFileCase` is a subclass of `DocTestCase`.

So both ways of creating a `unittest.TestSuite` run instances of `DocTestCase`. This is important for a subtle reason: when you run `doctest` functions yourself, you can control the `doctest` options in use directly, by passing option flags to `doctest` functions. However, if you're writing a `unittest` framework, `unittest` ultimately controls when and how tests get run. The framework author typically wants to control `doctest` reporting options (perhaps, e.g., specified by command line options), but there's no way to pass options through `unittest` to `doctest` test runners.

For this reason, `doctest` also supports a notion of `doctest` reporting flags specific to `unittest` support, via this function:

```
doctest.set_unittest_reportflags (flags)  
Set the doctest reporting flags to use.
```

Argument *flags* or's together option flags. See section *Option Flags and Directives*. Only "reporting flags" can be used.

This is a module-global setting, and affects all future doctests run by module `unittest`: the `runTest()` method of `DocTestCase` looks at the option flags specified for the test case when the `DocTestCase` instance was constructed. If no reporting flags were specified (which is the typical and expected case), `doctest`'s `unittest` reporting flags are or'd into the option flags, and the option flags so augmented are passed to the `DocTestRunner` instance created to run the doctest. If any reporting flags were specified when the `DocTestCase` instance was constructed, `doctest`'s `unittest` reporting flags are ignored.

The value of the `unittest` reporting flags in effect before the function was called is returned by the function. New in version 2.4.

## 25.2.6 Advanced API

The basic API is a simple wrapper that's intended to make doctest easy to use. It is fairly flexible, and should meet most users' needs; however, if you require more fine-grained control over testing, or wish to extend doctest's capabilities, then you should use the advanced API.

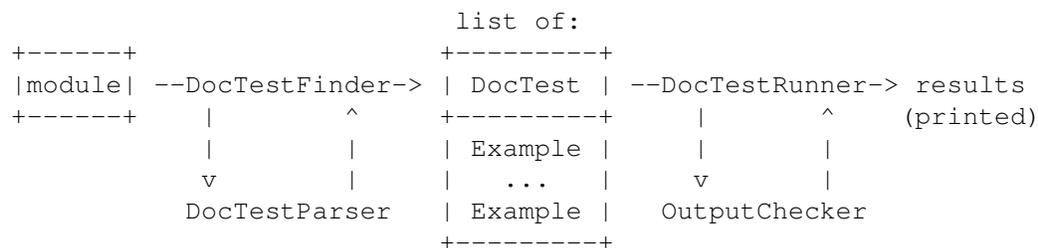
The advanced API revolves around two container classes, which are used to store the interactive examples extracted from doctest cases:

- **Example:** A single Python *statement*, paired with its expected output.
- **DocTest:** A collection of **Examples**, typically extracted from a single docstring or text file.

Additional processing classes are defined to find, parse, and run, and check doctest examples:

- **DocTestFinder:** Finds all docstrings in a given module, and uses a **DocTestParser** to create a **DocTest** from every docstring that contains interactive examples.
- **DocTestParser:** Creates a **DocTest** object from a string (such as an object's docstring).
- **DocTestRunner:** Executes the examples in a **DocTest**, and uses an **OutputChecker** to verify their output.
- **OutputChecker:** Compares the actual output from a doctest example with the expected output, and decides whether they match.

The relationships among these processing classes are summarized in the following diagram:



## DocTest Objects

**class** `doctest.DocTest` (*examples, globs, name, filename, lineno, docstring*)

A collection of doctest examples that should be run in a single namespace. The constructor arguments are used to initialize the attributes of the same names. New in version 2.4. **DocTest** defines the following attributes. They are initialized by the constructor, and should not be modified directly.

### **examples**

A list of **Example** objects encoding the individual interactive Python examples that should be run by this test.

### **globs**

The namespace (aka globals) that the examples should be run in. This is a dictionary mapping names to values. Any changes to the namespace made by the examples (such as binding new variables) will be reflected in **globs** after the test is run.

### **name**

A string name identifying the **DocTest**. Typically, this is the name of the object or file that the test was extracted from.

### **filename**

The name of the file that this **DocTest** was extracted from; or `None` if the filename is unknown, or if the **DocTest** was not extracted from a file.

**lineno**

The line number within `filename` where this `DocTest` begins, or `None` if the line number is unavailable. This line number is zero-based with respect to the beginning of the file.

**docstring**

The string that the test was extracted from, or 'None' if the string is unavailable, or if the test was not extracted from a string.

## Example Objects

**class** `doctest.Example` (*source*, *want*[, *exc\_msg*][, *lineno*][, *indent*][, *options*])

A single interactive example, consisting of a Python statement and its expected output. The constructor arguments are used to initialize the attributes of the same names. New in version 2.4. `Example` defines the following attributes. They are initialized by the constructor, and should not be modified directly.

**source**

A string containing the example's source code. This source code consists of a single Python statement, and always ends with a newline; the constructor adds a newline when necessary.

**want**

The expected output from running the example's source code (either from stdout, or a traceback in case of exception). `want` ends with a newline unless no output is expected, in which case it's an empty string. The constructor adds a newline when necessary.

**exc\_msg**

The exception message generated by the example, if the example is expected to generate an exception; or `None` if it is not expected to generate an exception. This exception message is compared against the return value of `traceback.format_exception_only()`. `exc_msg` ends with a newline unless it's `None`. The constructor adds a newline if needed.

**lineno**

The line number within the string containing this example where the example begins. This line number is zero-based with respect to the beginning of the containing string.

**indent**

The example's indentation in the containing string, i.e., the number of space characters that precede the example's first prompt.

**options**

A dictionary mapping from option flags to `True` or `False`, which is used to override default options for this example. Any option flags not contained in this dictionary are left at their default value (as specified by the `DocTestRunner`'s `optionflags`). By default, no options are set.

## DocTestFinder objects

**class** `doctest.DocTestFinder` ([*verbose*][, *parser*][, *recurse*][, *exclude\_empty*])

A processing class used to extract the `DocTests` that are relevant to a given object, from its docstring and the docstrings of its contained objects. `DocTests` can currently be extracted from the following object types: modules, functions, classes, methods, staticmethods, classmethods, and properties.

The optional argument `verbose` can be used to display the objects searched by the finder. It defaults to `False` (no output).

The optional argument `parser` specifies the `DocTestParser` object (or a drop-in replacement) that is used to extract doctests from docstrings.

If the optional argument `recurse` is false, then `DocTestFinder.find()` will only examine the given object, and not any contained objects.

If the optional argument `exclude_empty` is false, then `DocTestFinder.find()` will include tests for objects with empty docstrings. New in version 2.4. `DocTestFinder` defines the following method:

**find** (*obj*, [*name*], [*module*], [*globs*], [*extraglobs*])

Return a list of the `DocTests` that are defined by *obj*'s docstring, or by any of its contained objects' docstrings.

The optional argument *name* specifies the object's name; this name will be used to construct names for the returned `DocTests`. If *name* is not specified, then `obj.__name__` is used.

The optional parameter *module* is the module that contains the given object. If the module is not specified or is `None`, then the test finder will attempt to automatically determine the correct module. The object's module is used:

- As a default namespace, if *globs* is not specified.
- To prevent the `DocTestFinder` from extracting `DocTests` from objects that are imported from other modules. (Contained objects with modules other than *module* are ignored.)
- To find the name of the file containing the object.
- To help find the line number of the object within its file.

If *module* is `False`, no attempt to find the module will be made. This is obscure, of use mostly in testing `doctest` itself: if *module* is `False`, or is `None` but cannot be found automatically, then all objects are considered to belong to the (non-existent) module, so all contained objects will (recursively) be searched for `doctests`.

The globals for each `DocTest` is formed by combining *globs* and *extraglobs* (bindings in *extraglobs* override bindings in *globs*). A new shallow copy of the globals dictionary is created for each `DocTest`. If *globs* is not specified, then it defaults to the module's `__dict__`, if specified, or `{}` otherwise. If *extraglobs* is not specified, then it defaults to `{}`.

## DocTestParser objects

**class** `doctest.DocTestParser`

A processing class used to extract interactive examples from a string, and use them to create a `DocTest` object. New in version 2.4. `DocTestParser` defines the following methods:

**get\_doctest** (*string*, [*globs*], [*name*], [*filename*], [*lineno*])

Extract all `doctest` examples from the given string, and collect them into a `DocTest` object.

*globs*, *name*, *filename*, and *lineno* are attributes for the new `DocTest` object. See the documentation for `DocTest` for more information.

**get\_examples** (*string*, [*name*])

Extract all `doctest` examples from the given string, and return them as a list of `Example` objects. Line numbers are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

**parse** (*string*, [*name*])

Divide the given string into examples and intervening text, and return them as a list of alternating `Examples` and strings. Line numbers for the `Examples` are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

## DocTestRunner objects

**class** `doctest.DocTestRunner` ([*checker*], [*verbose*], [*optionflags*])

A processing class used to execute and verify the interactive examples in a `DocTest`.

The comparison between expected outputs and actual outputs is done by an `OutputChecker`. This comparison may be customized with a number of option flags; see section *Option Flags and Directives* for more information. If the option flags are insufficient, then the comparison may also be customized by passing a subclass of `OutputChecker` to the constructor.

The test runner's display output can be controlled in two ways. First, an output function can be passed to `TestRunner.run()`; this function will be called with strings that should be displayed. It defaults to `sys.stdout.write`. If capturing the output is not sufficient, then the display output can be also customized by subclassing `DocTestRunner`, and overriding the methods `report_start()`, `report_success()`, `report_unexpected_exception()`, and `report_failure()`.

The optional keyword argument `checker` specifies the `OutputChecker` object (or drop-in replacement) that should be used to compare the expected outputs to the actual outputs of doctest examples.

The optional keyword argument `verbose` controls the `DocTestRunner`'s verbosity. If `verbose` is `True`, then information is printed about each example, as it is run. If `verbose` is `False`, then only failures are printed. If `verbose` is unspecified, or `None`, then verbose output is used iff the command-line switch `-v` is used.

The optional keyword argument `optionflags` can be used to control how the test runner compares expected output to actual output, and how it displays failures. For more information, see section *Option Flags and Directives*. New in version 2.4. `DocTestParser` defines the following methods:

**report\_start** (*out, test, example*)

Report that the test runner is about to process the given example. This method is provided to allow subclasses of `DocTestRunner` to customize their output; it should not be called directly.

*example* is the example about to be processed. *test* is the test containing *example*. *out* is the output function that was passed to `DocTestRunner.run()`.

**report\_success** (*out, test, example, got*)

Report that the given example ran successfully. This method is provided to allow subclasses of `DocTestRunner` to customize their output; it should not be called directly.

*example* is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to `DocTestRunner.run()`.

**report\_failure** (*out, test, example, got*)

Report that the given example failed. This method is provided to allow subclasses of `DocTestRunner` to customize their output; it should not be called directly.

*example* is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to `DocTestRunner.run()`.

**report\_unexpected\_exception** (*out, test, example, exc\_info*)

Report that the given example raised an unexpected exception. This method is provided to allow subclasses of `DocTestRunner` to customize their output; it should not be called directly.

*example* is the example about to be processed. *exc\_info* is a tuple containing information about the unexpected exception (as returned by `sys.exc_info()`). *test* is the test containing *example*. *out* is the output function that was passed to `DocTestRunner.run()`.

**run** (*test[, compileflags][, out][, clear\_globs]*)

Run the examples in *test* (a `DocTest` object), and display the results using the writer function *out*.

The examples are run in the namespace `test.globs`. If `clear_globs` is true (the default), then this namespace will be cleared after the test runs, to help with garbage collection. If you would like to examine the namespace after the test completes, then use `clear_globs=False`.

*compileflags* gives the set of flags that should be used by the Python compiler when running the examples. If not specified, then it will default to the set of future-import flags that apply to *globs*.

The output of each example is checked using the `DocTestRunner`'s output checker, and the results are formatted by the `DocTestRunner.report_*` methods.

**summarize** (`[verbose]`)

Print a summary of all the test cases that have been run by this `DocTestRunner`, and return a *named tuple* `TestResults(failed, attempted)`.

The optional `verbose` argument controls how detailed the summary is. If the verbosity is not specified, then the `DocTestRunner`'s verbosity is used. Changed in version 2.6: Use a named tuple.

## OutputChecker objects

**class** `doctest.OutputChecker`

A class used to check the whether the actual output from a doctest example matches the expected output. `OutputChecker` defines two methods: `check_output()`, which compares a given pair of outputs, and returns true if they match; and `output_difference()`, which returns a string describing the differences between two outputs. New in version 2.4. `OutputChecker` defines the following methods:

**check\_output** (`want, got, optionflags`)

Return `True` iff the actual output from an example (`got`) matches the expected output (`want`). These strings are always considered to match if they are identical; but depending on what option flags the test runner is using, several non-exact match types are also possible. See section *Option Flags and Directives* for more information about option flags.

**output\_difference** (`example, got, optionflags`)

Return a string describing the differences between the expected output for a given example (`example`) and the actual output (`got`). `optionflags` is the set of option flags used to compare `want` and `got`.

## 25.2.7 Debugging

Doctest provides several mechanisms for debugging doctest examples:

- Several functions convert doctests to executable Python programs, which can be run under the Python debugger, `pdb`.
- The `DebugRunner` class is a subclass of `DocTestRunner` that raises an exception for the first failing example, containing information about that example. This information can be used to perform post-mortem debugging on the example.
- The `unittest` cases generated by `DocTestSuite()` support the `debug()` method defined by `unittest.TestCase`.
- You can add a call to `pdb.set_trace()` in a doctest example, and you'll drop into the Python debugger when that line is executed. Then you can inspect current values of variables, and so on. For example, suppose a `.py` contains just this module docstring:

```
"""
>>> def f(x):
...     g(x*2)
>>> def g(x):
...     print x+3
...     import pdb; pdb.set_trace()
>>> f(3)
9
"""
```

Then an interactive Python session may look like this:

```
>>> import a, doctest
>>> doctest.testmod(a)
--Return--
> <doctest a[1]>(3)g()->None
-> import pdb; pdb.set_trace()
(Pdb) list
  1     def g(x):
  2         print x+3
  3 ->     import pdb; pdb.set_trace()
[EOF]
(Pdb) print x
6
(Pdb) step
--Return--
> <doctest a[0]>(2)f()->None
-> g(x*2)
(Pdb) list
  1     def f(x):
  2 ->     g(x*2)
[EOF]
(Pdb) print x
3
(Pdb) step
--Return--
> <doctest a[2]>(1)?()->None
-> f(3)
(Pdb) cont
(0, 3)
>>>
```

Changed in version 2.4: The ability to use `pdb.set_trace()` usefully inside doctests was added.

Functions that convert doctests to Python code, and possibly run the synthesized code under the debugger:

`doctest.script_from_examples(s)`

Convert text with examples to a script.

Argument *s* is a string containing doctest examples. The string is converted to a Python script, where doctest examples in *s* are converted to regular code, and everything else is converted to Python comments. The generated script is returned as a string. For example,

```
import doctest
print doctest.script_from_examples(r"""
    Set x and y to 1 and 2.
    >>> x, y = 1, 2

    Print their sum:
    >>> print x+y
    3
""")
```

displays:

```
# Set x and y to 1 and 2.
x, y = 1, 2
#
```

```
# Print their sum:
print x+y
# Expected:
## 3
```

This function is used internally by other functions (see below), but can also be useful when you want to transform an interactive Python session into a Python script. New in version 2.4.

`doctest.testsource(module, name)`

Convert the doctest for an object to a script.

Argument *module* is a module object, or dotted name of a module, containing the object whose doctests are of interest. Argument *name* is the name (within the module) of the object with the doctests of interest. The result is a string, containing the object's docstring converted to a Python script, as described for `script_from_examples()` above. For example, if module `a.py` contains a top-level function `f()`, then

```
import a, doctest
print doctest.testsource(a, "a.f")
```

prints a script version of function `f()`'s docstring, with doctests converted to code, and the rest placed in comments. New in version 2.3.

`doctest.debug(module, name[, pm])`

Debug the doctests for an object.

The *module* and *name* arguments are the same as for function `testsource()` above. The synthesized Python script for the named object's docstring is written to a temporary file, and then that file is run under the control of the Python debugger, `pdb`.

A shallow copy of `module.__dict__` is used for both local and global execution context.

Optional argument *pm* controls whether post-mortem debugging is used. If *pm* has a true value, the script file is run directly, and the debugger gets involved only if the script terminates via raising an unhandled exception. If it does, then post-mortem debugging is invoked, via `pdb.post_mortem()`, passing the traceback object from the unhandled exception. If *pm* is not specified, or is false, the script is run under the debugger from the start, via passing an appropriate `execfile()` call to `pdb.run()`. New in version 2.3. Changed in version 2.4: The *pm* argument was added.

`doctest.debug_src(src[, pm][, globs])`

Debug the doctests in a string.

This is like function `debug()` above, except that a string containing doctest examples is specified directly, via the *src* argument.

Optional argument *pm* has the same meaning as in function `debug()` above.

Optional argument *globs* gives a dictionary to use as both local and global execution context. If not specified, or None, an empty dictionary is used. If specified, a shallow copy of the dictionary is used. New in version 2.4.

The `DebugRunner` class, and the special exceptions it may raise, are of most interest to testing framework authors, and will only be sketched here. See the source code, and especially `DebugRunner`'s docstring (which is a doctest!) for more details:

**class** `doctest.DebugRunner` (*[checker][, verbose][, optionflags]*)

A subclass of `DocTestRunner` that raises an exception as soon as a failure is encountered. If an unexpected exception occurs, an `UnexpectedException` exception is raised, containing the test, the example, and the original exception. If the output doesn't match, then a `DocTestFailure` exception is raised, containing the test, the example, and the actual output.

For information about the constructor parameters and methods, see the documentation for `DocTestRunner` in section *Advanced API*.

There are two exceptions that may be raised by `DebugRunner` instances:

**exception** `doctest.DocTestFailure` (*test, example, got*)

An exception raised by `DocTestRunner` to signal that a doctest example’s actual output did not match its expected output. The constructor arguments are used to initialize the attributes of the same names.

`DocTestFailure` defines the following attributes:

`DocTestFailure.test`

The `DocTest` object that was being run when the example failed.

`DocTestFailure.example`

The `Example` that failed.

`DocTestFailure.got`

The example’s actual output.

**exception** `doctest.UnexpectedException` (*test, example, exc\_info*)

An exception raised by `DocTestRunner` to signal that a doctest example raised an unexpected exception. The constructor arguments are used to initialize the attributes of the same names.

`UnexpectedException` defines the following attributes:

`UnexpectedException.test`

The `DocTest` object that was being run when the example failed.

`UnexpectedException.example`

The `Example` that failed.

`UnexpectedException.exc_info`

A tuple containing information about the unexpected exception, as returned by `sys.exc_info()`.

### 25.2.8 Soapbox

As mentioned in the introduction, `doctest` has grown to have three primary uses:

1. Checking examples in docstrings.
2. Regression testing.
3. Executable documentation / literate testing.

These uses have different requirements, and it is important to distinguish them. In particular, filling your docstrings with obscure test cases makes for bad documentation.

When writing a docstring, choose docstring examples with care. There’s an art to this that needs to be learned—it may not be natural at first. Examples should add genuine value to the documentation. A good example can often be worth many words. If done with care, the examples will be invaluable for your users, and will pay back the time it takes to collect them many times over as the years go by and things change. I’m still amazed at how often one of my `doctest` examples stops working after a “harmless” change.

Doctest also makes an excellent tool for regression testing, especially if you don’t skimp on explanatory text. By interleaving prose and examples, it becomes much easier to keep track of what’s actually being tested, and why. When a test fails, good prose can make it much easier to figure out what the problem is, and how it should be fixed. It’s true that you could write extensive comments in code-based testing, but few programmers do. Many have found that using doctest approaches instead leads to much clearer tests. Perhaps this is simply because doctest makes writing prose a little easier than writing code, while writing comments in code is a little harder. I think it goes deeper than just that: the natural attitude when writing a doctest-based test is that you want to explain the fine points of your software, and illustrate them with examples. This in turn naturally leads to test files that start with the simplest features, and

logically progress to complications and edge cases. A coherent narrative is the result, instead of a collection of isolated functions that test isolated bits of functionality seemingly at random. It's a different attitude, and produces different results, blurring the distinction between testing and explaining.

Regression testing is best confined to dedicated objects or files. There are several options for organizing tests:

- Write text files containing test cases as interactive examples, and test the files using `testfile()` or `DocFileSuite()`. This is recommended, although is easiest to do for new projects, designed from the start to use doctest.
- Define functions named `__regtest_topic` that consist of single docstrings, containing test cases for the named topics. These functions can be included in the same file as the module, or separated out into a separate test file.
- Define a `__test__` dictionary mapping from regression test topics to docstrings containing test cases.

## 25.3 unittest — Unit testing framework

New in version 2.1. (If you are already familiar with the basic concepts of testing, you might want to skip to *the list of assert methods*.)

The Python unit testing framework, sometimes referred to as “PyUnit,” is a Python language version of JUnit, by Kent Beck and Erich Gamma. JUnit is, in turn, a Java version of Kent’s Smalltalk testing framework. Each is the de facto standard unit testing framework for its respective language.

`unittest` supports test automation, sharing of setup and shutdown code for tests, aggregation of tests into collections, and independence of the tests from the reporting framework. The `unittest` module provides classes that make it easy to support these qualities for a set of tests.

To achieve this, `unittest` supports some important concepts:

**test fixture** A *test fixture* represents the preparation needed to perform one or more tests, and any associated cleanup actions. This may involve, for example, creating temporary or proxy databases, directories, or starting a server process.

**test case** A *test case* is the smallest unit of testing. It checks for a specific response to a particular set of inputs. `unittest` provides a base class, `TestCase`, which may be used to create new test cases.

**test suite** A *test suite* is a collection of test cases, test suites, or both. It is used to aggregate tests that should be executed together.

**test runner** A *test runner* is a component which orchestrates the execution of tests and provides the outcome to the user. The runner may use a graphical interface, a textual interface, or return a special value to indicate the results of executing the tests.

The test case and test fixture concepts are supported through the `TestCase` and `FunctionTestCase` classes; the former should be used when creating new tests, and the latter can be used when integrating existing test code with a `unittest`-driven framework. When building test fixtures using `TestCase`, the `setUp()` and `tearDown()` methods can be overridden to provide initialization and cleanup for the fixture. With `FunctionTestCase`, existing functions can be passed to the constructor for these purposes. When the test is run, the fixture initialization is run first; if it succeeds, the cleanup method is run after the test has been executed, regardless of the outcome of the test. Each instance of the `TestCase` will only be used to run a single test method, so a new fixture is created for each test.

Test suites are implemented by the `TestSuite` class. This class allows individual tests and test suites to be aggregated; when the suite is executed, all tests added directly to the suite and in “child” test suites are run.

A test runner is an object that provides a single method, `run()`, which accepts a `TestCase` or `TestSuite` object as a parameter, and returns a result object. The class `TestResult` is provided for use as the result object. `unittest` provides the `TextTestRunner` as an example test runner which reports test results on the standard error stream by

default. Alternate runners can be implemented for other environments (such as graphical environments) without any need to derive from a specific class.

### See Also:

**Module `doctest`** Another test-support module with a very different flavor.

**unittest2: A backport of new unittest features for Python 2.4-2.6** Many new features were added to unittest in Python 2.7, including test discovery. unittest2 allows you to use these features with earlier versions of Python.

**Simple Smalltalk Testing: With Patterns** Kent Beck's original paper on testing frameworks using the pattern shared by `unittest`.

**Nose and `py.test`** Third-party unittest frameworks with a lighter-weight syntax for writing tests. For example, `assert func(10) == 42`.

**The Python Testing Tools Taxonomy** An extensive list of Python testing tools including functional testing frameworks and mock object libraries.

**Testing in Python Mailing List** A special-interest-group for discussion of testing, and testing tools, in Python.

### 25.3.1 Basic example

The `unittest` module provides a rich set of tools for constructing and running tests. This section demonstrates that a small subset of the tools suffice to meet the needs of most users.

Here is a short script to test three functions from the `random` module:

```
import random
import unittest

class TestSequenceFunctions(unittest.TestCase):

    def setUp(self):
        self.seq = range(10)

    def test_shuffle(self):
        # make sure the shuffled sequence does not lose any elements
        random.shuffle(self.seq)
        self.seq.sort()
        self.assertEqual(self.seq, range(10))

        # should raise an exception for an immutable sequence
        self.assertRaises(TypeError, random.shuffle, (1,2,3))

    def test_choice(self):
        element = random.choice(self.seq)
        self.assertTrue(element in self.seq)

    def test_sample(self):
        with self.assertRaises(ValueError):
            random.sample(self.seq, 20)
        for element in random.sample(self.seq, 5):
            self.assertTrue(element in self.seq)

if __name__ == '__main__':
    unittest.main()
```

A testcase is created by subclassing `unittest.TestCase`. The three individual tests are defined with methods whose names start with the letters `test`. This naming convention informs the test runner about which methods represent tests.

The crux of each test is a call to `assertEqual()` to check for an expected result; `assertTrue()` to verify a condition; or `assertRaises()` to verify that an expected exception gets raised. These methods are used instead of the `assert` statement so the test runner can accumulate all test results and produce a report.

When a `setUp()` method is defined, the test runner will run that method prior to each test. Likewise, if a `tearDown()` method is defined, the test runner will invoke that method after each test. In the example, `setUp()` was used to create a fresh sequence for each test.

The final block shows a simple way to run the tests. `unittest.main()` provides a command-line interface to the test script. When run from the command line, the above script produces an output that looks like this:

```
...
-----
Ran 3 tests in 0.000s

OK
```

Instead of `unittest.main()`, there are other ways to run the tests with a finer level of control, less terse output, and no requirement to be run from the command line. For example, the last two lines may be replaced with:

```
suite = unittest.TestLoader().loadTestsFromTestCase(TestSequenceFunctions)
unittest.TextTestRunner(verbosity=2).run(suite)
```

Running the revised script from the interpreter or another script produces the following output:

```
test_choice (__main__.TestSequenceFunctions) ... ok
test_sample (__main__.TestSequenceFunctions) ... ok
test_shuffle (__main__.TestSequenceFunctions) ... ok

-----
Ran 3 tests in 0.110s

OK
```

The above examples show the most commonly used `unittest` features which are sufficient to meet many everyday testing needs. The remainder of the documentation explores the full feature set from first principles.

## 25.3.2 Command-Line Interface

The `unittest` module can be used from the command line to run tests from modules, classes or even individual test methods:

```
python -m unittest test_module1 test_module2
python -m unittest test_module.TestClass
python -m unittest test_module.TestClass.test_method
```

You can pass in a list with any combination of module names, and fully qualified class or method names.

You can run tests with more detail (higher verbosity) by passing in the `-v` flag:

```
python -m unittest -v test_module
```

For a list of all the command-line options:

```
python -m unittest -h
```

Changed in version 2.7: In earlier versions it was only possible to run individual test methods and not modules or classes.

### Command-line options

`unittest` supports these command-line options:

**-b, -buffer**

The standard output and standard error streams are buffered during the test run. Output during a passing test is discarded. Output is echoed normally on test fail or error and is added to the failure messages.

**-c, -catch**

Control-C during the test run waits for the current test to end and then reports all the results so far. A second control-C raises the normal `KeyboardInterrupt` exception.

See [Signal Handling](#) for the functions that provide this functionality.

**-f, -failfast**

Stop the test run on the first error or failure.

New in version 2.7: The command-line options `-b`, `-c` and `-f` were added. The command line can also be used for test discovery, for running all of the tests in a project or just a subset.

### 25.3.3 Test Discovery

New in version 2.7. `unittest` supports simple test discovery. In order to be compatible with test discovery, all of the test files must be *modules* or *packages* importable from the top-level directory of the project (this means that their filenames must be valid *identifiers*).

Test discovery is implemented in `TestLoader.discover()`, but can also be used from the command line. The basic command-line usage is:

```
cd project_directory
python -m unittest discover
```

The `discover` sub-command has the following options:

**-v, -verbose**

Verbose output

**-s directory**

Directory to start discovery (‘.’ default)

**-p pattern**

Pattern to match test files (‘test\*.py’ default)

**-t directory**

Top level directory of project (defaults to start directory)

The `-s`, `-p`, and `-t` options can be passed in as positional arguments in that order. The following two command lines are equivalent:

```
python -m unittest discover -s project_directory -p '*_test.py'
python -m unittest discover project_directory '*_test.py'
```

As well as being a path it is possible to pass a package name, for example `myproject.subpackage.test`, as the start directory. The package name you supply will then be imported and its location on the filesystem will be used as the start directory.

**Caution:** Test discovery loads tests by importing them. Once test discovery has found all the test files from the start directory you specify it turns the paths into package names to import. For example `foo/bar/baz.py` will be imported as `foo.bar.baz`.

If you have a package installed globally and attempt test discovery on a different copy of the package then the import *could* happen from the wrong place. If this happens test discovery will warn you and exit.

If you supply the start directory as a package name rather than a path to a directory then discover assumes that whichever location it imports from is the location you intended, so you will not get the warning.

Test modules and packages can customize test loading and discovery by through the `load_tests` protocol.

### 25.3.4 Organizing test code

The basic building blocks of unit testing are *test cases* — single scenarios that must be set up and checked for correctness. In `unittest`, test cases are represented by instances of `unittest`'s `TestCase` class. To make your own test cases you must write subclasses of `TestCase`, or use `FunctionTestCase`.

An instance of a `TestCase`-derived class is an object that can completely run a single test method, together with optional set-up and tidy-up code.

The testing code of a `TestCase` instance should be entirely self contained, such that it can be run either in isolation or in arbitrary combination with any number of other test cases.

The simplest `TestCase` subclass will simply override the `runTest()` method in order to perform specific testing code:

```
import unittest

class DefaultWidgetSizeTestCase(unittest.TestCase):
    def runTest(self):
        widget = Widget('The widget')
        self.assertEqual(widget.size(), (50, 50), 'incorrect default size')
```

Note that in order to test something, we use one of the `assert*`() methods provided by the `TestCase` base class. If the test fails, an exception will be raised, and `unittest` will identify the test case as a *failure*. Any other exceptions will be treated as *errors*. This helps you identify where the problem is: *failures* are caused by incorrect results - a 5 where you expected a 6. *Errors* are caused by incorrect code - e.g., a `TypeError` caused by an incorrect function call.

The way to run a test case will be described later. For now, note that to construct an instance of such a test case, we call its constructor without arguments:

```
testCase = DefaultWidgetSizeTestCase()
```

Now, such test cases can be numerous, and their set-up can be repetitive. In the above case, constructing a `Widget` in each of 100 `Widget` test case subclasses would mean unsightly duplication.

Luckily, we can factor out such set-up code by implementing a method called `setUp()`, which the testing framework will automatically call for us when we run the test:

```
import unittest

class SimpleWidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

class DefaultWidgetSizeTestCase(SimpleWidgetTestCase):
    def runTest(self):
```

```
self.assertEqual(self.widget.size(), (50,50),
                 'incorrect default size')
```

```
class WidgetResizeTestCase(SimpleWidgetTestCase):
    def runTest(self):
        self.widget.resize(100,150)
        self.assertEqual(self.widget.size(), (100,150),
                         'wrong size after resize')
```

If the `setUp()` method raises an exception while the test is running, the framework will consider the test to have suffered an error, and the `runTest()` method will not be executed.

Similarly, we can provide a `tearDown()` method that tidies up after the `runTest()` method has been run:

```
import unittest
```

```
class SimpleWidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def tearDown(self):
        self.widget.dispose()
        self.widget = None
```

If `setUp()` succeeded, the `tearDown()` method will be run whether `runTest()` succeeded or not.

Such a working environment for the testing code is called a *fixture*.

Often, many small test cases will use the same fixture. In this case, we would end up subclassing `SimpleWidgetTestCase` into many small one-method classes such as `DefaultWidgetSizeTestCase`. This is time-consuming and discouraging, so in the same vein as JUnit, `unittest` provides a simpler mechanism:

```
import unittest
```

```
class WidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def tearDown(self):
        self.widget.dispose()
        self.widget = None

    def test_default_size(self):
        self.assertEqual(self.widget.size(), (50,50),
                         'incorrect default size')

    def test_resize(self):
        self.widget.resize(100,150)
        self.assertEqual(self.widget.size(), (100,150),
                         'wrong size after resize')
```

Here we have not provided a `runTest()` method, but have instead provided two different test methods. Class instances will now each run one of the `test_*()` methods, with `self.widget` created and destroyed separately for each instance. When creating an instance we must specify the test method it is to run. We do this by passing the method name in the constructor:

```
defaultSizeTestCase = WidgetTestCase('test_default_size')
resizeTestCase = WidgetTestCase('test_resize')
```

Test case instances are grouped together according to the features they test. `unittest` provides a mechanism for this: the *test suite*, represented by `unittest`'s `TestSuite` class:

```
widgetTestSuite = unittest.TestSuite()
widgetTestSuite.addTest(WidgetTestCase('test_default_size'))
widgetTestSuite.addTest(WidgetTestCase('test_resize'))
```

For the ease of running tests, as we will see later, it is a good idea to provide in each test module a callable object that returns a pre-built test suite:

```
def suite():
    suite = unittest.TestSuite()
    suite.addTest(WidgetTestCase('test_default_size'))
    suite.addTest(WidgetTestCase('test_resize'))
    return suite
```

or even:

```
def suite():
    tests = ['test_default_size', 'test_resize']

    return unittest.TestSuite(map(WidgetTestCase, tests))
```

Since it is a common pattern to create a `TestCase` subclass with many similarly named test functions, `unittest` provides a `TestLoader` class that can be used to automate the process of creating a test suite and populating it with individual tests. For example,

```
suite = unittest.TestLoader().loadTestsFromTestCase(WidgetTestCase)
```

will create a test suite that will run `WidgetTestCase.test_default_size()` and `WidgetTestCase.test_resize`. `TestLoader` uses the 'test' method name prefix to identify test methods automatically.

Note that the order in which the various test cases will be run is determined by sorting the test function names with respect to the built-in ordering for strings.

Often it is desirable to group suites of test cases together, so as to run tests for the whole system at once. This is easy, since `TestSuite` instances can be added to a `TestSuite` just as `TestCase` instances can be added to a `TestSuite`:

```
suite1 = module1.TheTestSuite()
suite2 = module2.TheTestSuite()
alltests = unittest.TestSuite([suite1, suite2])
```

You can place the definitions of test cases and test suites in the same modules as the code they are to test (such as `widget.py`), but there are several advantages to placing the test code in a separate module, such as `test_widget.py`:

- The test module can be run standalone from the command line.
- The test code can more easily be separated from shipped code.
- There is less temptation to change test code to fit the code it tests without a good reason.
- Test code should be modified much less frequently than the code it tests.
- Tested code can be refactored more easily.
- Tests for modules written in C must be in separate modules anyway, so why not be consistent?
- If the testing strategy changes, there is no need to change the source code.

### 25.3.5 Re-using old test code

Some users will find that they have existing test code that they would like to run from `unittest`, without converting every old test function to a `TestCase` subclass.

For this reason, `unittest` provides a `FunctionTestCase` class. This subclass of `TestCase` can be used to wrap an existing test function. Set-up and tear-down functions can also be provided.

Given the following test function:

```
def testSomething():
    something = makeSomething()
    assert something.name is not None
    # ...
```

one can create an equivalent test case instance as follows:

```
testcase = unittest.FunctionTestCase(testSomething)
```

If there are additional set-up and tear-down methods that should be called as part of the test case's operation, they can also be provided like so:

```
testcase = unittest.FunctionTestCase(testSomething,
                                     setUp=makeSomethingDB,
                                     tearDown=deleteSomethingDB)
```

To make migrating existing test suites easier, `unittest` supports tests raising `AssertionError` to indicate test failure. However, it is recommended that you use the explicit `TestCase.fail*()` and `TestCase.assert*()` methods instead, as future versions of `unittest` may treat `AssertionError` differently.

---

**Note:** Even though `FunctionTestCase` can be used to quickly convert an existing test base over to a `unittest`-based system, this approach is not recommended. Taking the time to set up proper `TestCase` subclasses will make future test refactorings infinitely easier.

---

In some cases, the existing tests may have been written using the `doctest` module. If so, `doctest` provides a `DocTestSuite` class that can automatically build `unittest.TestSuite` instances from the existing `doctest`-based tests.

### 25.3.6 Skipping tests and expected failures

New in version 2.7. `unittest` supports skipping individual test methods and even whole classes of tests. In addition, it supports marking a test as a “expected failure,” a test that is broken and will fail, but shouldn't be counted as a failure on a `TestResult`.

Skipping a test is simply a matter of using the `skip()` decorator or one of its conditional variants.

Basic skipping looks like this:

```
class MyTestCase(unittest.TestCase):

    @unittest.skip("demonstrating skipping")
    def test_nothing(self):
        self.fail("shouldn't happen")

    @unittest.skipIf(mylib.__version__ < (1, 3),
                    "not supported in this library version")
    def test_format(self):
        # Tests that work for only a certain version of the library.
```

```

    pass

    @unittest.skipUnless(sys.platform.startswith("win"), "requires Windows")
    def test_windows_support(self):
        # windows specific testing code
    pass

```

This is the output of running the example above in verbose mode:

```

test_format (__main__.MyTestCase) ... skipped 'not supported in this library version'
test_nothing (__main__.MyTestCase) ... skipped 'demonstrating skipping'
test_windows_support (__main__.MyTestCase) ... skipped 'requires Windows'

```

```
-----
Ran 3 tests in 0.005s
```

```
OK (skipped=3)
```

Classes can be skipped just like methods:

```

@unittest.skip("showing class skipping")
class MySkippedTestCase(unittest.TestCase):
    def test_not_run(self):
        pass

```

`TestCase.setUp()` can also skip the test. This is useful when a resource that needs to be set up is not available.

Expected failures use the `expectedFailure()` decorator.

```

class ExpectedFailureTestCase(unittest.TestCase):
    @unittest.expectedFailure
    def test_fail(self):
        self.assertEqual(1, 0, "broken")

```

It's easy to roll your own skipping decorators by making a decorator that calls `skip()` on the test when it wants it to be skipped. This decorator skips the test unless the passed object has a certain attribute:

```

def skipUnlessHasattr(obj, attr):
    if hasattr(obj, attr):
        return lambda func: func
    return unittest.skip("{0!r} doesn't have {1!r}".format(obj, attr))

```

The following decorators implement test skipping and expected failures:

`unittest.skip(reason)`

Unconditionally skip the decorated test. *reason* should describe why the test is being skipped.

`unittest.skipIf(condition, reason)`

Skip the decorated test if *condition* is true.

`unittest.skipUnless(condition, reason)`

Skip the decorated test unless *condition* is true.

`unittest.expectedFailure()`

Mark the test as an expected failure. If the test fails when run, the test is not counted as a failure.

Skipped tests will not have `setUp()` or `tearDown()` run around them. Skipped classes will not have `setUpClass()` or `tearDownClass()` run.

## 25.3.7 Classes and functions

This section describes in depth the API of `unittest`.

### Test cases

**class** `unittest.TestCase` (*methodName='runTest'*)

Instances of the `TestCase` class represent the smallest testable units in the `unittest` universe. This class is intended to be used as a base class, with specific tests being implemented by concrete subclasses. This class implements the interface needed by the test runner to allow it to drive the test, and methods that the test code can use to check for and report various kinds of failure.

Each instance of `TestCase` will run a single test method: the method named *methodName*. If you remember, we had an earlier example that went something like this:

```
def suite():
    suite = unittest.TestSuite()
    suite.addTest(WidgetTestCase('test_default_size'))
    suite.addTest(WidgetTestCase('test_resize'))
    return suite
```

Here, we create two instances of `WidgetTestCase`, each of which runs a single test.

*methodName* defaults to `runTest()`.

`TestCase` instances provide three groups of methods: one group used to run the test, another used by the test implementation to check conditions and report failures, and some inquiry methods allowing information about the test itself to be gathered.

Methods in the first group (running the test) are:

#### **setUp()**

Method called to prepare the test fixture. This is called immediately before calling the test method; any exception raised by this method will be considered an error rather than a test failure. The default implementation does nothing.

#### **tearDown()**

Method called immediately after the test method has been called and the result recorded. This is called even if the test method raised an exception, so the implementation in subclasses may need to be particularly careful about checking internal state. Any exception raised by this method will be considered an error rather than a test failure. This method will only be called if the `setUp()` succeeds, regardless of the outcome of the test method. The default implementation does nothing.

#### **setUpClass()**

A class method called before tests in an individual class run. `setUpClass` is called with the class as the only argument and must be decorated as a `classmethod()`:

```
@classmethod
def setUpClass(cls):
    ...
```

See [Class and Module Fixtures](#) for more details. New in version 2.7.

#### **tearDownClass()**

A class method called after tests in an individual class have run. `tearDownClass` is called with the class as the only argument and must be decorated as a `classmethod()`:

```
@classmethod
def tearDownClass(cls):
    ...
```

See [Class and Module Fixtures](#) for more details. New in version 2.7.

**run** (*result=None*)

Run the test, collecting the result into the test result object passed as *result*. If *result* is omitted or `None`, a temporary result object is created (by calling the `defaultTestResult()` method) and used. The result object is not returned to `run()`'s caller.

The same effect may be had by simply calling the `TestCase` instance.

**skipTest** (*reason*)

Calling this during a test method or `setUp()` skips the current test. See [Skipping tests and expected failures](#) for more information. New in version 2.7.

**debug** ()

Run the test without collecting the result. This allows exceptions raised by the test to be propagated to the caller, and can be used to support running tests under a debugger.

The `TestCase` class provides a number of methods to check for and report failures, such as:

Method	Checks that	New in
<code>assertEqual(a, b)</code>	<code>a == b</code>	
<code>assertNotEqual(a, b)</code>	<code>a != b</code>	
<code>assertTrue(x)</code>	<code>bool(x) is True</code>	
<code>assertFalse(x)</code>	<code>bool(x) is False</code>	
<code>assertIs(a, b)</code>	<code>a is b</code>	2.7
<code>assertIsNot(a, b)</code>	<code>a is not b</code>	2.7
<code>assertIsNone(x)</code>	<code>x is None</code>	2.7
<code>assertIsNotNone(x)</code>	<code>x is not None</code>	2.7
<code>assertIn(a, b)</code>	<code>a in b</code>	2.7
<code>assertNotIn(a, b)</code>	<code>a not in b</code>	2.7
<code>assertIsInstance(a, b)</code>	<code>isinstance(a, b)</code>	2.7
<code>assertNotIsInstance(a, b)</code>	<code>not isinstance(a, b)</code>	2.7

All the assert methods (except `assertRaises()`, `assertRaisesRegexp()`) accept a *msg* argument that, if specified, is used as the error message on failure (see also [longMessage](#)).

**assertEqual** (*first, second, msg=None*)

Test that *first* and *second* are equal. If the values do not compare equal, the test will fail.

In addition, if *first* and *second* are the exact same type and one of list, tuple, dict, set, frozenset or unicode or any type that a subclass registers with `addTypeEqualityFunc()` the type-specific equality function will be called in order to generate a more useful default error message (see also the [list of type-specific methods](#)). Changed in version 2.7: Added the automatic calling of type-specific equality function.

**assertNotEqual** (*first, second, msg=None*)

Test that *first* and *second* are not equal. If the values do compare equal, the test will fail.

**assertTrue** (*expr, msg=None*)

**assertFalse** (*expr, msg=None*)

Test that *expr* is true (or false).

Note that this is equivalent to `bool(expr) is True` and not to `expr is True` (use `assertIs(expr, True)` for the latter). This method should also be avoided when more specific methods are available (e.g. `assertEqual(a, b)` instead of `assertTrue(a == b)`), because they provide a better error message in case of failure.

**assertIs** (*first, second, msg=None*)

**assertIsNot** (*first, second, msg=None*)

Test that *first* and *second* evaluate (or don't evaluate) to the same object. New in version 2.7.

**assertIsNone** (*expr, msg=None*)

**assertIsNotNone** (*expr, msg=None*)

Test that *expr* is (or is not) None. New in version 2.7.

**assertIn** (*first, second, msg=None*)

**assertNotIn** (*first, second, msg=None*)

Test that *first* is (or is not) in *second*. New in version 2.7.

**assertIsInstance** (*obj, cls, msg=None*)

**assertNotIsInstance** (*obj, cls, msg=None*)

Test that *obj* is (or is not) an instance of *cls* (which can be a class or a tuple of classes, as supported by `isinstance()`). To check for the exact type, use `assertIs(type(obj), cls)`. New in version 2.7.

It is also possible to check that exceptions and warnings are raised using the following methods:

Method	Checks that	New in
<code>assertRaises(exc, fun, *args, **kwargs)</code>	<code>fun(*args, **kwargs)</code> raises <i>exc</i>	2.7
<code>assertRaisesRegexp(exc, re, fun, *args, **kwargs)</code>	<code>fun(*args, **kwargs)</code> raises <i>exc</i> and the message matches <i>re</i>	

**assertRaises** (*exception, callable, \*args, \*\*kwargs*)

**assertRaises** (*exception*)

Test that an exception is raised when *callable* is called with any positional or keyword arguments that are also passed to `assertRaises()`. The test passes if *exception* is raised, is an error if another exception is raised, or fails if no exception is raised. To catch any of a group of exceptions, a tuple containing the exception classes may be passed as *exception*.

If only the *exception* argument is given, returns a context manager so that the code under test can be written inline rather than as a function:

```
with self.assertRaises(SomeException):
    do_something()
```

The context manager will store the caught exception object in its `exception` attribute. This can be useful if the intention is to perform additional checks on the exception raised:

```
with self.assertRaises(SomeException) as cm:
    do_something()

the_exception = cm.exception
self.assertEqual(the_exception.error_code, 3)
```

Changed in version 2.7: Added the ability to use `assertRaises()` as a context manager.

**assertRaisesRegexp** (*exception, regexp, callable, \*args, \*\*kwargs*)

**assertRaisesRegexp** (*exception, regexp*)

Like `assertRaises()` but also tests that *regexp* matches on the string representation of the raised exception. *regexp* may be a regular expression object or a string containing a regular expression suitable for use by `re.search()`. Examples:

```
self.assertRaisesRegexp(ValueError, 'invalid literal for.*XYZ$',
                        int, 'XYZ')
```

or:

```
with self.assertRaisesRegexp(ValueError, 'literal'):
    int('XYZ')
```

New in version 2.7.

There are also other methods used to perform more specific checks, such as:

Method	Checks that	New in
<code>assertAlmostEqual(a, b)</code>	<code>round(a-b, 7) == 0</code>	
<code>assertNotAlmostEqual(a, b)</code>	<code>round(a-b, 7) != 0</code>	
<code>assertGreater(a, b)</code>	<code>a &gt; b</code>	2.7
<code>assertGreaterEqual(a, b)</code>	<code>a &gt;= b</code>	2.7
<code>assertLess(a, b)</code>	<code>a &lt; b</code>	2.7
<code>assertLessEqual(a, b)</code>	<code>a &lt;= b</code>	2.7
<code>assertRegexpMatches(s, re)</code>	<code>regex.search(s)</code>	2.7
<code>assertNotRegexpMatches(s, re)</code>	<code>not regex.search(s)</code>	2.7
<code>assertItemsEqual(a, b)</code>	<code>sorted(a) == sorted(b)</code> and works with unhashable objs	2.7
<code>assertDictContainsSubset(a, b)</code>	all the key/value pairs in <i>a</i> exist in <i>b</i>	2.7

**assertAlmostEqual** (*first, second, places=7, msg=None, delta=None*)

**assertNotAlmostEqual** (*first, second, places=7, msg=None, delta=None*)

Test that *first* and *second* are approximately (or not approximately) equal by computing the difference, rounding to the given number of decimal *places* (default 7), and comparing to zero. Note that these methods round the values to the given number of *decimal places* (i.e. like the `round()` function) and not *significant digits*.

If *delta* is supplied instead of *places* then the difference between *first* and *second* must be less (or more) than *delta*.

Supplying both *delta* and *places* raises a `TypeError`. Changed in version 2.7: `assertAlmostEqual()` automatically considers almost equal objects that compare equal. `assertNotAlmostEqual()` automatically fails if the objects compare equal. Added the *delta* keyword argument.

**assertGreater** (*first, second, msg=None*)

**assertGreaterEqual** (*first, second, msg=None*)

**assertLess** (*first, second, msg=None*)

**assertLessEqual** (*first, second, msg=None*)

Test that *first* is respectively `>`, `>=`, `<` or `<=` than *second* depending on the method name. If not, the test will fail:

```
>>> self.assertGreaterEqual(3, 4)
AssertionError: "3" unexpectedly not greater than or equal to "4"
```

New in version 2.7.

**assertRegexpMatches** (*text, regexp, msg=None*)

Test that a *regexp* search matches *text*. In case of failure, the error message will include the pattern and the *text* (or the pattern and the part of *text* that unexpectedly matched). *regexp* may be a regular expression object or a string containing a regular expression suitable for use by `re.search()`. New in version 2.7.

**assertNotRegexpMatches** (*text, regexp, msg=None*)

Verifies that a *regexp* search does not match *text*. Fails with an error message including the pattern and

the part of *text* that matches. *regex* may be a regular expression object or a string containing a regular expression suitable for use by `re.search()`. New in version 2.7.

**assertItemsEqual** (*actual, expected, msg=None*)

Test that sequence *expected* contains the same elements as *actual*, regardless of their order. When they don't, an error message listing the differences between the sequences will be generated.

Duplicate elements are *not* ignored when comparing *actual* and *expected*. It verifies if each element has the same count in both sequences. It is the equivalent of `assertEqual(sorted(expected), sorted(actual))` but it works with sequences of unhashable objects as well. New in version 2.7.

**assertDictContainsSubset** (*expected, actual, msg=None*)

Tests whether the key/value pairs in dictionary *actual* are a superset of those in *expected*. If not, an error message listing the missing keys and mismatched values is generated. New in version 2.7. Deprecated since version 3.2.

The `assertEqual()` method dispatches the equality check for objects of the same type to different type-specific methods. These methods are already implemented for most of the built-in types, but it's also possible to register new methods using `addTypeEqualityFunc()`:

**addTypeEqualityFunc** (*typeobj, function*)

Registers a type-specific method called by `assertEqual()` to check if two objects of exactly the same *typeobj* (not subclasses) compare equal. *function* must take two positional arguments and a third `msg=None` keyword argument just as `assertEqual()` does. It must raise `self.failureException(msg)` when inequality between the first two parameters is detected – possibly providing useful information and explaining the inequalities in details in the error message. New in version 2.7.

The list of type-specific methods automatically used by `assertEqual()` are summarized in the following table. Note that it's usually not necessary to invoke these methods directly.

Method	Used to compare	New in
<code>assertMultiLineEqual(a, b)</code>	strings	2.7
<code>assertSequenceEqual(a, b)</code>	sequences	2.7
<code>assertListEqual(a, b)</code>	lists	2.7
<code>assertTupleEqual(a, b)</code>	tuples	2.7
<code>assertSetEqual(a, b)</code>	sets or frozensets	2.7
<code>assertDictEqual(a, b)</code>	dicts	2.7

**assertMultiLineEqual** (*first, second, msg=None*)

Test that the multiline string *first* is equal to the string *second*. When not equal a diff of the two strings highlighting the differences will be included in the error message. This method is used by default when comparing strings with `assertEqual()`. New in version 2.7.

**assertSequenceEqual** (*seq1, seq2, msg=None, seq\_type=None*)

Tests that two sequences are equal. If a *seq\_type* is supplied, both *seq1* and *seq2* must be instances of *seq\_type* or a failure will be raised. If the sequences are different an error message is constructed that shows the difference between the two.

This method is not called directly by `assertEqual()`, but it's used to implement `assertListEqual()` and `assertTupleEqual()`. New in version 2.7.

**assertListEqual** (*list1, list2, msg=None*)

**assertTupleEqual** (*tuple1, tuple2, msg=None*)

Tests that two lists or tuples are equal. If not, an error message is constructed that shows only the differences between the two. An error is also raised if either of the parameters are of the wrong type. These methods are used by default when comparing lists or tuples with `assertEqual()`. New in version 2.7.

**assertSetEqual** (*set1, set2, msg=None*)

Tests that two sets are equal. If not, an error message is constructed that lists the differences between the

sets. This method is used by default when comparing sets or frozensets with `assertEqual()`.

Fails if either of `set1` or `set2` does not have a `set.difference()` method. New in version 2.7.

**assertDictEqual** (*expected, actual, msg=None*)

Test that two dictionaries are equal. If not, an error message is constructed that shows the differences in the dictionaries. This method will be used by default to compare dictionaries in calls to `assertEqual()`. New in version 2.7.

Finally the `TestCase` provides the following methods and attributes:

**fail** (*msg=None*)

Signals a test failure unconditionally, with `msg` or `None` for the error message.

**failureException**

This class attribute gives the exception raised by the test method. If a test framework needs to use a specialized exception, possibly to carry additional information, it must subclass this exception in order to “play fair” with the framework. The initial value of this attribute is `AssertionError`.

**longMessage**

If set to `True` then any explicit failure message you pass in to the *assert methods* will be appended to the end of the normal failure message. The normal messages contain useful information about the objects involved, for example the message from `assertEqual` shows you the repr of the two unequal objects. Setting this attribute to `True` allows you to have a custom error message in addition to the normal one.

This attribute defaults to `False`, meaning that a custom message passed to an assert method will silence the normal message.

The class setting can be overridden in individual tests by assigning an instance attribute to `True` or `False` before calling the assert methods. New in version 2.7.

**maxDiff**

This attribute controls the maximum length of diffs output by assert methods that report diffs on failure. It defaults to 80\*8 characters. Assert methods affected by this attribute are `assertSequenceEqual()` (including all the sequence comparison methods that delegate to it), `assertDictEqual()` and `assertMultiLineEqual()`.

Setting `maxDiff` to `None` means that there is no maximum length of diffs. New in version 2.7.

Testing frameworks can use the following methods to collect information on the test:

**countTestCases** ()

Return the number of tests represented by this test object. For `TestCase` instances, this will always be 1.

**defaultTestResult** ()

Return an instance of the test result class that should be used for this test case class (if no other result instance is provided to the `run()` method).

For `TestCase` instances, this will always be an instance of `TestResult`; subclasses of `TestCase` should override this as necessary.

**id** ()

Return a string identifying the specific test case. This is usually the full name of the test method, including the module and class name.

**shortDescription** ()

Returns a description of the test, or `None` if no description has been provided. The default implementation of this method returns the first line of the test method’s docstring, if available, or `None`.

**addCleanup** (*function, \*args, \*\*kwargs*)

Add a function to be called after `tearDown()` to cleanup resources used during the test. Functions will

be called in reverse order to the order they are added (LIFO). They are called with any arguments and keyword arguments passed into `addCleanup()` when they are added.

If `setUp()` fails, meaning that `tearDown()` is not called, then any cleanup functions added will still be called. New in version 2.7.

**doCleanups()**

This method is called unconditionally after `tearDown()`, or after `setUp()` if `setUp()` raises an exception.

It is responsible for calling all the cleanup functions added by `addCleanup()`. If you need cleanup functions to be called *prior* to `tearDown()` then you can call `doCleanups()` yourself.

`doCleanups()` pops methods off the stack of cleanup functions one at a time, so it can be called at any time. New in version 2.7.

**class unittest.FunctionTestCase** (*testFunc, setUp=None, tearDown=None, description=None*)

This class implements the portion of the `TestCase` interface which allows the test runner to drive the test, but does not provide the methods which test code can use to check and report errors. This is used to create test cases using legacy test code, allowing it to be integrated into a `unittest`-based test framework.

**Deprecated aliases**

For historical reasons, some of the `TestCase` methods had one or more aliases that are now deprecated. The following table lists the correct names along with their deprecated aliases:

Method Name	Deprecated alias(es)
<code>assertEqual()</code>	<code>failUnlessEqual</code> , <code>assertEquals</code>
<code>assertNotEqual()</code>	<code>failIfEqual</code>
<code>assertTrue()</code>	<code>failUnless</code> , <code>assert_</code>
<code>assertFalse()</code>	<code>failIf</code>
<code>assertRaises()</code>	<code>failUnlessRaises</code>
<code>assertAlmostEqual()</code>	<code>failUnlessAlmostEqual</code>
<code>assertNotAlmostEqual()</code>	<code>failIfAlmostEqual</code>

Deprecated since version 2.7: the aliases listed in the second column

**Grouping tests**

**class unittest.TestSuite** (*tests=()*)

This class represents an aggregation of individual tests cases and test suites. The class presents the interface needed by the test runner to allow it to be run as any other test case. Running a `TestSuite` instance is the same as iterating over the suite, running each test individually.

If *tests* is given, it must be an iterable of individual test cases or other test suites that will be used to build the suite initially. Additional methods are provided to add test cases and suites to the collection later on.

`TestSuite` objects behave much like `TestCase` objects, except they do not actually implement a test. Instead, they are used to aggregate tests into groups of tests that should be run together. Some additional methods are available to add tests to `TestSuite` instances:

**addTest** (*test*)

Add a `TestCase` or `TestSuite` to the suite.

**addTests** (*tests*)

Add all the tests from an iterable of `TestCase` and `TestSuite` instances to this test suite.

This is equivalent to iterating over *tests*, calling `addTest()` for each element.

`TestSuite` shares the following methods with `TestCase`:

**run** (*result*)

Run the tests associated with this suite, collecting the result into the test result object passed as *result*. Note that unlike `TestCase.run()`, `TestSuite.run()` requires the result object to be passed in.

**debug** ()

Run the tests associated with this suite without collecting the result. This allows exceptions raised by the test to be propagated to the caller and can be used to support running tests under a debugger.

**countTestCases** ()

Return the number of tests represented by this test object, including all individual tests and sub-suites.

**\_\_iter\_\_** ()

Tests grouped by a `TestSuite` are always accessed by iteration. Subclasses can lazily provide tests by overriding `__iter__()`. Note that this method maybe called several times on a single suite (for example when counting tests or comparing for equality) so the tests returned must be the same for repeated iterations. Changed in version 2.7: In earlier versions the `TestSuite` accessed tests directly rather than through iteration, so overriding `__iter__()` wasn't sufficient for providing tests.

In the typical usage of a `TestSuite` object, the `run()` method is invoked by a `TestRunner` rather than by the end-user test harness.

## Loading and running tests

**class** `unittest.TestLoader`

The `TestLoader` class is used to create test suites from classes and modules. Normally, there is no need to create an instance of this class; the `unittest` module provides an instance that can be shared as `unittest.defaultTestLoader`. Using a subclass or instance, however, allows customization of some configurable properties.

`TestLoader` objects have the following methods:

**loadTestsFromTestCase** (*testCaseClass*)

Return a suite of all tests cases contained in the `TestCase`-derived `testCaseClass`.

**loadTestsFromModule** (*module*)

Return a suite of all tests cases contained in the given module. This method searches *module* for classes derived from `TestCase` and creates an instance of the class for each test method defined for the class.

---

**Note:** While using a hierarchy of `TestCase`-derived classes can be convenient in sharing fixtures and helper functions, defining test methods on base classes that are not intended to be instantiated directly does not play well with this method. Doing so, however, can be useful when the fixtures are different and defined in subclasses.

---

If a module provides a `load_tests` function it will be called to load the tests. This allows modules to customize test loading. This is the `load_tests` protocol. Changed in version 2.7: Support for `load_tests` added.

**loadTestsFromName** (*name*, *module=None*)

Return a suite of all tests cases given a string specifier.

The specifier *name* is a “dotted name” that may resolve either to a module, a test case class, a test method within a test case class, a `TestSuite` instance, or a callable object which returns a `TestCase` or `TestSuite` instance. These checks are applied in the order listed here; that is, a method on a possible test case class will be picked up as “a test method within a test case class”, rather than “a callable object”.

For example, if you have a module `SampleTests` containing a `TestCase`-derived class `SampleTestCase` with three test methods (`test_one()`, `test_two()`, and `test_three()`), the specifier `'SampleTests.SampleTestCase'` would cause this method to return a suite which will run all three test methods. Using the specifier `'SampleTests.SampleTestCase.test_two'` would cause it to return a test suite which will run only the `test_two()` test method. The specifier can refer to modules and packages which have not been imported; they will be imported as a side-effect.

The method optionally resolves *name* relative to the given *module*.

**loadTestsFromNames** (*names*, *module=None*)

Similar to `loadTestsFromName()`, but takes a sequence of names rather than a single name. The return value is a test suite which supports all the tests defined for each name.

**getTestCaseNames** (*testCaseClass*)

Return a sorted sequence of method names found within *testCaseClass*; this should be a subclass of `TestCase`.

**discover** (*start\_dir*, *pattern='test\*.py'*, *top\_level\_dir=None*)

Find and return all test modules from the specified start directory, recursing into subdirectories to find them. Only test files that match *pattern* will be loaded. (Using shell style pattern matching.) Only module names that are importable (i.e. are valid Python identifiers) will be loaded.

All test modules must be importable from the top level of the project. If the start directory is not the top level directory then the top level directory must be specified separately.

If importing a module fails, for example due to a syntax error, then this will be recorded as a single error and discovery will continue.

If a test package name (directory with `__init__.py`) matches the pattern then the package will be checked for a `load_tests` function. If this exists then it will be called with *loader*, *tests*, *pattern*.

If `load_tests` exists then discovery does *not* recurse into the package, `load_tests` is responsible for loading all tests in the package.

The pattern is deliberately not stored as a loader attribute so that packages can continue discovery themselves. *top\_level\_dir* is stored so `load_tests` does not need to pass this argument in to `loader.discover()`.

*start\_dir* can be a dotted module name as well as a directory. New in version 2.7.

The following attributes of a `TestLoader` can be configured either by subclassing or assignment on an instance:

**testMethodPrefix**

String giving the prefix of method names which will be interpreted as test methods. The default value is `'test'`.

This affects `getTestCaseNames()` and all the `loadTestsFrom*` () methods.

**sortTestMethodsUsing**

Function to be used to compare method names when sorting them in `getTestCaseNames()` and all the `loadTestsFrom*` () methods. The default value is the built-in `cmp()` function; the attribute can also be set to `None` to disable the sort.

**suiteClass**

Callable object that constructs a test suite from a list of tests. No methods on the resulting object are needed. The default value is the `TestSuite` class.

This affects all the `loadTestsFrom*` () methods.

**class** `unittest.TestResult`

This class is used to compile information about which tests have succeeded and which have failed.

A `TestResult` object stores the results of a set of tests. The `TestCase` and `TestSuite` classes ensure that results are properly recorded; test authors do not need to worry about recording the outcome of tests.

Testing frameworks built on top of `unittest` may want access to the `TestResult` object generated by running a set of tests for reporting purposes; a `TestResult` instance is returned by the `TestRunner.run()` method for this purpose.

`TestResult` instances have the following attributes that will be of interest when inspecting the results of running a set of tests:

**errors**

A list containing 2-tuples of `TestCase` instances and strings holding formatted tracebacks. Each tuple represents a test which raised an unexpected exception. Changed in version 2.2: Contains formatted tracebacks instead of `sys.exc_info()` results.

**failures**

A list containing 2-tuples of `TestCase` instances and strings holding formatted tracebacks. Each tuple represents a test where a failure was explicitly signalled using the `TestCase.fail*()` or `TestCase.assert*()` methods. Changed in version 2.2: Contains formatted tracebacks instead of `sys.exc_info()` results.

**skipped**

A list containing 2-tuples of `TestCase` instances and strings holding the reason for skipping the test. New in version 2.7.

**expectedFailures**

A list containing 2-tuples of `TestCase` instances and strings holding formatted tracebacks. Each tuple represents an expected failure of the test case.

**unexpectedSuccesses**

A list containing `TestCase` instances that were marked as expected failures, but succeeded.

**shouldStop**

Set to `True` when the execution of tests should stop by `stop()`.

**testsRun**

The total number of tests run so far.

**buffer**

If set to `true`, `sys.stdout` and `sys.stderr` will be buffered in between `startTest()` and `stopTest()` being called. Collected output will only be echoed onto the real `sys.stdout` and `sys.stderr` if the test fails or errors. Any output is also attached to the failure / error message. New in version 2.7.

**failfast**

If set to `true` `stop()` will be called on the first failure or error, halting the test run. New in version 2.7.

**wasSuccessful()**

Return `True` if all tests run so far have passed, otherwise returns `False`.

**stop()**

This method can be called to signal that the set of tests being run should be aborted by setting the `shouldStop` attribute to `True`. `TestRunner` objects should respect this flag and return without running any additional tests.

For example, this feature is used by the `TextTestRunner` class to stop the test framework when the user signals an interrupt from the keyboard. Interactive tools which provide `TestRunner` implementations can use this in a similar manner.

The following methods of the `TestResult` class are used to maintain the internal data structures, and may be extended in subclasses to support additional reporting requirements. This is particularly useful in building tools

which support interactive reporting while tests are being run.

**startTest** (*test*)

Called when the test case *test* is about to be run.

**stopTest** (*test*)

Called after the test case *test* has been executed, regardless of the outcome.

**startTestRun** (*test*)

Called once before any tests are executed. New in version 2.7.

**stopTestRun** (*test*)

Called once after all tests are executed. New in version 2.7.

**addError** (*test, err*)

Called when the test case *test* raises an unexpected exception *err* is a tuple of the form returned by `sys.exc_info()`: (type, value, traceback).

The default implementation appends a tuple (*test*, *formatted\_err*) to the instance's `errors` attribute, where *formatted\_err* is a formatted traceback derived from *err*.

**addFailure** (*test, err*)

Called when the test case *test* signals a failure. *err* is a tuple of the form returned by `sys.exc_info()`: (type, value, traceback).

The default implementation appends a tuple (*test*, *formatted\_err*) to the instance's `failures` attribute, where *formatted\_err* is a formatted traceback derived from *err*.

**addSuccess** (*test*)

Called when the test case *test* succeeds.

The default implementation does nothing.

**addSkip** (*test, reason*)

Called when the test case *test* is skipped. *reason* is the reason the test gave for skipping.

The default implementation appends a tuple (*test*, *reason*) to the instance's `skipped` attribute.

**addExpectedFailure** (*test, err*)

Called when the test case *test* fails, but was marked with the `expectedFailure()` decorator.

The default implementation appends a tuple (*test*, *formatted\_err*) to the instance's `expectedFailures` attribute, where *formatted\_err* is a formatted traceback derived from *err*.

**addUnexpectedSuccess** (*test*)

Called when the test case *test* was marked with the `expectedFailure()` decorator, but succeeded.

The default implementation appends the test to the instance's `unexpectedSuccesses` attribute.

**class** `unittest.TextTestResult` (*stream, descriptions, verbosity*)

A concrete implementation of `TestResult` used by the `TextTestRunner`. New in version 2.7: This class was previously named `_TextTestResult`. The old name still exists as an alias but is deprecated.

`unittest.defaultTestLoader`

Instance of the `TestLoader` class intended to be shared. If no customization of the `TestLoader` is needed, this instance can be used instead of repeatedly creating new instances.

**class** `unittest.TextTestRunner` (*stream=sys.stderr, descriptions=True, verbosity=1*)

A basic test runner implementation which prints results on standard error. It has a few configurable parameters, but is essentially very simple. Graphical applications which run test suites should provide alternate implementations.

**`_makeResult()`**

This method returns the instance of `TestResult` used by `run()`. It is not intended to be called directly, but can be overridden in subclasses to provide a custom `TestResult`.

`_makeResult()` instantiates the class or callable passed in the `TextTestRunner` constructor as the `resultclass` argument. It defaults to `TextTestResult` if no `resultclass` is provided. The result class is instantiated with the following arguments:

```
stream, descriptions, verbosity
```

```
unittest.main([module[, defaultTest[, argv[, testRunner[, testLoader[, exit[, verbosity[, failfast[,
catchbreak[, buffer]]]]]]]]]])
```

A command-line program that loads a set of tests from `module` and runs them; this is primarily for making test modules conveniently executable. The simplest use for this function is to include the following line at the end of a test script:

```
if __name__ == '__main__':
    unittest.main()
```

You can run tests with more detailed information by passing in the `verbosity` argument:

```
if __name__ == '__main__':
    unittest.main(verbosity=2)
```

The `argv` argument can be a list of options passed to the program, with the first element being the program name. If not specified or `None`, the values of `sys.argv` are used.

The `testRunner` argument can either be a test runner class or an already created instance of it. By default `main` calls `sys.exit()` with an exit code indicating success or failure of the tests run.

The `testLoader` argument has to be a `TestLoader` instance, and defaults to `defaultTestLoader`.

`main` supports being used from the interactive interpreter by passing in the argument `exit=False`. This displays the result on standard output without calling `sys.exit()`:

```
>>> from unittest import main
>>> main(module='test_module', exit=False)
```

The `failfast`, `catchbreak` and `buffer` parameters have the same effect as the same-name [command-line options](#).

Calling `main` actually returns an instance of the `TestProgram` class. This stores the result of the tests run as the `result` attribute. Changed in version 2.7: The `exit`, `verbosity`, `failfast`, `catchbreak` and `buffer` parameters were added.

**load\_tests Protocol**

New in version 2.7. Modules or packages can customize how tests are loaded from them during normal test runs or test discovery by implementing a function called `load_tests`.

If a test module defines `load_tests` it will be called by `TestLoader.loadTestsFromModule()` with the following arguments:

```
load_tests(loader, standard_tests, None)
```

It should return a `TestSuite`.

*loader* is the instance of `TestLoader` doing the loading. *standard\_tests* are the tests that would be loaded by default from the module. It is common for test modules to only want to add or remove tests from the standard set of tests. The third argument is used when loading packages as part of test discovery.

A typical `load_tests` function that loads tests from a specific set of `TestCase` classes may look like:

```
test_cases = (TestCase1, TestCase2, TestCase3)

def load_tests(loader, tests, pattern):
    suite = TestSuite()
    for test_class in test_cases:
        tests = loader.loadTestsFromTestCase(test_class)
        suite.addTests(tests)
    return suite
```

If discovery is started, either from the command line or by calling `TestLoader.discover()`, with a pattern that matches a package name then the package `__init__.py` will be checked for `load_tests`.

---

**Note:** The default pattern is `'test*.py'`. This matches all Python files that start with `'test'` but *won't* match any test directories.

A pattern like `'test*'` will match test packages as well as modules.

---

If the package `__init__.py` defines `load_tests` then it will be called and discovery not continued into the package. `load_tests` is called with the following arguments:

```
load_tests(loader, standard_tests, pattern)
```

This should return a `TestSuite` representing all the tests from the package. (`standard_tests` will only contain tests collected from `__init__.py`.)

Because the pattern is passed into `load_tests` the package is free to continue (and potentially modify) test discovery. A 'do nothing' `load_tests` function for a test package would look like:

```
def load_tests(loader, standard_tests, pattern):
    # top level directory cached on loader instance
    this_dir = os.path.dirname(__file__)
    package_tests = loader.discover(start_dir=this_dir, pattern=pattern)
    standard_tests.addTests(package_tests)
    return standard_tests
```

### 25.3.8 Class and Module Fixtures

Class and module level fixtures are implemented in `TestSuite`. When the test suite encounters a test from a new class then `tearDownClass()` from the previous class (if there is one) is called, followed by `setUpClass()` from the new class.

Similarly if a test is from a different module from the previous test then `tearDownModule` from the previous module is run, followed by `setUpModule` from the new module.

After all the tests have run the final `tearDownClass` and `tearDownModule` are run.

Note that shared fixtures do not play well with [potential] features like test parallelization and they break test isolation. They should be used with care.

The default ordering of tests created by the unittest test loaders is to group all tests from the same modules and classes together. This will lead to `setUpClass` / `setUpModule` (etc) being called exactly once per class and module. If

you randomize the order, so that tests from different modules and classes are adjacent to each other, then these shared fixture functions may be called multiple times in a single test run.

Shared fixtures are not intended to work with suites with non-standard ordering. A `BaseTestSuite` still exists for frameworks that don't want to support shared fixtures.

If there are any exceptions raised during one of the shared fixture functions the test is reported as an error. Because there is no corresponding test instance an `_ErrorHandler` object (that has the same interface as a `TestCase`) is created to represent the error. If you are just using the standard unittest test runner then this detail doesn't matter, but if you are a framework author it may be relevant.

### setUpClass and tearDownClass

These must be implemented as class methods:

```
import unittest

class Test(unittest.TestCase):
    @classmethod
    def setUpClass(cls):
        cls._connection = createExpensiveConnectionObject()

    @classmethod
    def tearDownClass(cls):
        cls._connection.destroy()
```

If you want the `setUpClass` and `tearDownClass` on base classes called then you must call up to them yourself. The implementations in `TestCase` are empty.

If an exception is raised during a `setUpClass` then the tests in the class are not run and the `tearDownClass` is not run. Skipped classes will not have `setUpClass` or `tearDownClass` run. If the exception is a `SkipTest` exception then the class will be reported as having been skipped instead of as an error.

### setUpModule and tearDownModule

These should be implemented as functions:

```
def setUpModule():
    createConnection()

def tearDownModule():
    closeConnection()
```

If an exception is raised in a `setUpModule` then none of the tests in the module will be run and the `tearDownModule` will not be run. If the exception is a `SkipTest` exception then the module will be reported as having been skipped instead of as an error.

## 25.3.9 Signal Handling

The `-c/--catch` command-line option to unittest, along with the `catchbreak` parameter to `unittest.main()`, provide more friendly handling of control-C during a test run. With catch break behavior enabled control-C will allow the currently running test to complete, and the test run will then end and report all the results so far. A second control-c will raise a `KeyboardInterrupt` in the usual way.

The control-c handling signal handler attempts to remain compatible with code or tests that install their own `signal.SIGINT` handler. If the unittest handler is called but *isn't* the installed `signal.SIGINT` handler,

i.e. it has been replaced by the system under test and delegated to, then it calls the default handler. This will normally be the expected behavior by code that replaces an installed handler and delegates to it. For individual tests that need `unittest` control-c handling disabled the `removeHandler()` decorator can be used.

There are a few utility functions for framework authors to enable control-c handling functionality within test frameworks.

`unittest.installHandler()`

Install the control-c handler. When a `signal.SIGINT` is received (usually in response to the user pressing control-c) all registered results have `stop()` called. New in version 2.7.

`unittest.registerResult(result)`

Register a `TestResult` object for control-c handling. Registering a result stores a weak reference to it, so it doesn't prevent the result from being garbage collected.

Registering a `TestResult` object has no side-effects if control-c handling is not enabled, so test frameworks can unconditionally register all results they create independently of whether or not handling is enabled. New in version 2.7.

`unittest.removeResult(result)`

Remove a registered result. Once a result has been removed then `stop()` will no longer be called on that result object in response to a control-c. New in version 2.7.

`unittest.removeHandler(function=None)`

When called without arguments this function removes the control-c handler if it has been installed. This function can also be used as a test decorator to temporarily remove the handler whilst the test is being executed:

```
@unittest.removeHandler
def test_signal_handling(self):
    ...
```

New in version 2.7.

## 25.4 2to3 - Automated Python 2 to 3 code translation

2to3 is a Python program that reads Python 2.x source code and applies a series of *fixers* to transform it into valid Python 3.x code. The standard library contains a rich set of fixers that will handle almost all code. 2to3 supporting library `lib2to3` is, however, a flexible and generic library, so it is possible to write your own fixers for 2to3. `lib2to3` could also be adapted to custom applications in which Python code needs to be edited automatically.

### 25.4.1 Using 2to3

2to3 will usually be installed with the Python interpreter as a script. It is also located in the `Tools/scripts` directory of the Python root.

2to3's basic arguments are a list of files or directories to transform. The directories are to recursively traversed for Python sources.

Here is a sample Python 2.x source file, `example.py`:

```
def greet(name):
    print "Hello, {0}!".format(name)
print "What's your name?"
name = raw_input()
greet(name)
```

It can be converted to Python 3.x code via 2to3 on the command line:

```
$ 2to3 example.py
```

A diff against the original source file is printed. 2to3 can also write the needed modifications right back to the source file. (A backup of the original file is made unless `-n` is also given.) Writing the changes back is enabled with the `-w` flag:

```
$ 2to3 -w example.py
```

After transformation, `example.py` looks like this:

```
def greet(name):
    print("Hello, {0}!".format(name))
print("What's your name?")
name = input()
greet(name)
```

Comments and exact indentation are preserved throughout the translation process.

By default, 2to3 runs a set of *predefined fixers*. The `-l` flag lists all available fixers. An explicit set of fixers to run can be given with `-f`. Likewise the `-x` explicitly disables a fixer. The following example runs only the `imports` and `has_key` fixers:

```
$ 2to3 -f imports -f has_key example.py
```

This command runs every fixer except the `apply` fixer:

```
$ 2to3 -x apply example.py
```

Some fixers are *explicit*, meaning they aren't run by default and must be listed on the command line to be run. Here, in addition to the default fixers, the `idioms` fixer is run:

```
$ 2to3 -f all -f idioms example.py
```

Notice how passing `all` enables all default fixers.

Sometimes 2to3 will find a place in your source code that needs to be changed, but 2to3 cannot fix automatically. In this case, 2to3 will print a warning beneath the diff for a file. You should address the warning in order to have compliant 3.x code.

2to3 can also refactor doctests. To enable this mode, use the `-d` flag. Note that *only* doctests will be refactored. This also doesn't require the module to be valid Python. For example, doctest like examples in a reST document could also be refactored with this option.

The `-v` option enables output of more information on the translation process.

Since some print statements can be parsed as function calls or statements, 2to3 cannot always read files containing the print function. When 2to3 detects the presence of the `from __future__ import print_function` compiler directive, it modifies its internal grammar to interpret `print()` as a function. This change can also be enabled manually with the `-p` flag. Use `-p` to run fixers on code that already has had its print statements converted.

The `-o` or `--output-dir` option allows specification of an alternate directory for processed output files to be written to. The `-n` flag is required when using this as backup files do not make sense when not overwriting the input files. New in version 2.7.3: The `-o` option was added. The `-W` or `--write-unchanged-files` flag tells 2to3 to always write output files even if no changes were required to the file. This is most useful with `-o` so that an entire Python source tree is copied with translation from one directory to another. This option implies the `-w` flag as it would not make sense otherwise. New in version 2.7.3: The `-W` flag was added. The `--add-suffix` option specifies a string to append to all output filenames. The `-n` flag is required when specifying this as backups are not necessary when writing to different filenames. Example:

```
$ 2to3 -n -W --add-suffix=3 example.py
```

Will cause a converted file named `example.py3` to be written. New in version 2.7.3: The `--add-suffix` option was added. To translate an entire project from one directory tree to another use:

```
$ 2to3 --output-dir=python3-version/mycode -W -n python2-version/mycode
```

### 25.4.2 Fixers

Each step of transforming code is encapsulated in a fixer. The command `2to3 -l` lists them. As *documented above*, each can be turned on and off individually. They are described here in more detail.

#### **apply**

Removes usage of `apply()`. For example `apply(function, *args, **kwargs)` is converted to `function(*args, **kwargs)`.

#### **basestring**

Converts `basestring` to `str`.

#### **buffer**

Converts `buffer` to `memoryview`. This fixer is optional because the `memoryview` API is similar but not exactly the same as that of `buffer`.

#### **callable**

Converts `callable(x)` to `isinstance(x, collections.Callable)`, adding an import to `collections` if needed. Note `callable(x)` has returned in Python 3.2, so if you do not intend to support Python 3.1, you can disable this fixer.

#### **dict**

Fixes dictionary iteration methods. `dict.iteritems()` is converted to `dict.items()`, `dict.iterkeys()` to `dict.keys()`, and `dict.itervalues()` to `dict.values()`. Similarly, `dict.viewitems()`, `dict.viewkeys()` and `dict.viewvalues()` are converted respectively to `dict.items()`, `dict.keys()` and `dict.values()`. It also wraps existing usages of `dict.items()`, `dict.keys()`, and `dict.values()` in a call to `list`.

#### **except**

Converts `except X, T` to `except X as T`.

#### **exec**

Converts the `exec` statement to the `exec()` function.

#### **execfile**

Removes usage of `execfile()`. The argument to `execfile()` is wrapped in calls to `open()`, `compile()`, and `exec()`.

#### **exitfunc**

Changes assignment of `sys.exitfunc` to use of the `atexit` module.

#### **filter**

Wraps `filter()` usage in a `list` call.

#### **funcattrs**

Fixes function attributes that have been renamed. For example, `my_function.func_closure` is converted to `my_function.__closure__`.

#### **future**

Removes from `__future__ import new_feature` statements.

#### **getcwdu**

Renames `os.getcwdu()` to `os.getcwd()`.

#### **has\_key**

Changes `dict.has_key(key)` to `key in dict`.

**idioms**

This optional fixer performs several transformations that make Python code more idiomatic. Type comparisons like `type(x) is SomeClass` and `type(x) == SomeClass` are converted to `isinstance(x, SomeClass)`. `while 1` becomes `while True`. This fixer also tries to make use of `sorted()` in appropriate places. For example, this block

```
L = list(some_iterable)
L.sort()
```

is changed to

```
L = sorted(some_iterable)
```

**import**

Detects sibling imports and converts them to relative imports.

**imports**

Handles module renames in the standard library.

**imports2**

Handles other modules renames in the standard library. It is separate from the `imports` fixer only because of technical limitations.

**input**

Converts `input(prompt)` to `eval(input(prompt))`

**intern**

Converts `intern()` to `sys.intern()`.

**isinstance**

Fixes duplicate types in the second argument of `isinstance()`. For example, `isinstance(x, (int, int))` is converted to `isinstance(x, (int))`.

**itertools\_imports**

Removes imports of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()`. Imports of `itertools.ifilterfalse()` are also changed to `itertools.filterfalse()`.

**itertools**

Changes usage of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()` to their built-in equivalents. `itertools.ifilterfalse()` is changed to `itertools.filterfalse()`.

**long**

Strips the L suffix on long literals and renames `long` to `int`.

**map**

Wraps `map()` in a `list` call. It also changes `map(None, x)` to `list(x)`. Using `from future_builtins import map` disables this fixer.

**metaclass**

Converts the old metaclass syntax (`__metaclass__ = Meta` in the class body) to the new (`class X(metaclass=Meta)`).

**methodattrs**

Fixes old method attribute names. For example, `meth.im_func` is converted to `meth.__func__`.

**ne**

Converts the old not-equal syntax, `<>`, to `!=`.

### **next**

Converts the use of iterator's `next()` methods to the `next()` function. It also renames `next()` methods to `__next__()`.

### **nonzero**

Renames `__nonzero__()` to `__bool__()`.

### **numliterals**

Converts octal literals into the new syntax.

### **paren**

Add extra parenthesis where they are required in list comprehensions. For example, `[x for x in 1, 2]` becomes `[x for x in (1, 2)]`.

### **print**

Converts the `print` statement to the `print()` function.

### **raise**

Converts `raise E, V` to `raise E(V)`, and `raise E, V, T` to `raise E(V).with_traceback(T)`. If `E` is a tuple, the translation will be incorrect because substituting tuples for exceptions has been removed in Python 3.

### **raw\_input**

Converts `raw_input()` to `input()`.

### **reduce**

Handles the move of `reduce()` to `functools.reduce()`.

### **renames**

Changes `sys.maxint` to `sys.maxsize`.

### **repr**

Replaces backtick `repr` with the `repr()` function.

### **set\_literal**

Replaces use of the `set` constructor with set literals. This fixer is optional.

### **standard\_error**

Renames `StandardError` to `Exception`.

### **sys\_exc**

Changes the deprecated `sys.exc_value`, `sys.exc_type`, `sys.exc_traceback` to use `sys.exc_info()`.

### **throw**

Fixes the API change in generator's `throw()` method.

### **tuple\_params**

Removes implicit tuple parameter unpacking. This fixer inserts temporary variables.

### **types**

Fixes code broken from the removal of some members in the `types` module.

### **unicode**

Renames `unicode` to `str`.

### **urllib**

Handles the rename of `urllib` and `urllib2` to the `urllib` package.

### **ws\_comma**

Removes excess whitespace from comma separated items. This fixer is optional.

**xrange**

Renames `xrange()` to `range()` and wraps existing `range()` calls with `list`.

**xreadlines**

Changes for `x` in `file.xreadlines()` to `for x in file`.

**zip**

Wraps `zip()` usage in a `list` call. This is disabled when `from future_builtins import zip` appears.

### 25.4.3 lib2to3 - 2to3's library

---

**Note:** The `lib2to3` API should be considered unstable and may change drastically in the future.

---

## 25.5 test — Regression tests package for Python

---

**Note:** The `test` package is meant for internal use by Python only. It is documented for the benefit of the core developers of Python. Any use of this package outside of Python's standard library is discouraged as code mentioned here can change or be removed without notice between releases of Python.

---

The `test` package contains all regression tests for Python as well as the modules `test.test_support` and `test.regrtest`. `test.test_support` is used to enhance your tests while `test.regrtest` drives the testing suite.

Each module in the `test` package whose name starts with `test_` is a testing suite for a specific module or feature. All new tests should be written using the `unittest` or `doctest` module. Some older tests are written using a “traditional” testing style that compares output printed to `sys.stdout`; this style of test is considered deprecated.

**See Also:**

**Module `unittest`** Writing PyUnit regression tests.

**Module `doctest`** Tests embedded in documentation strings.

### 25.5.1 Writing Unit Tests for the test package

It is preferred that tests that use the `unittest` module follow a few guidelines. One is to name the test module by starting it with `test_` and end it with the name of the module being tested. The test methods in the test module should start with `test_` and end with a description of what the method is testing. This is needed so that the methods are recognized by the test driver as test methods. Also, no documentation string for the method should be included. A comment (such as `# Tests function returns only True or False`) should be used to provide documentation for test methods. This is done because documentation strings get printed out if they exist and thus what test is being run is not stated.

A basic boilerplate is often used:

```
import unittest
from test import test_support

class MyTestCase1(unittest.TestCase):

    # Only use setUp() and tearDown() if necessary
```

```
def setUp(self):
    ... code to execute in preparation for tests ...

def tearDown(self):
    ... code to execute to clean up after tests ...

def test_feature_one(self):
    # Test feature one.
    ... testing code ...

def test_feature_two(self):
    # Test feature two.
    ... testing code ...

... more test methods ...

class MyTestCase2(unittest.TestCase):
    ... same structure as MyTestCase1 ...

... more test classes ...

def test_main():
    test_support.run_unittest(MyTestCase1,
                              MyTestCase2,
                              ... list other tests ...
                              )

if __name__ == '__main__':
    test_main()
```

This boilerplate code allows the testing suite to be run by `test.regrtest` as well as on its own as a script.

The goal for regression testing is to try to break code. This leads to a few guidelines to be followed:

- The testing suite should exercise all classes, functions, and constants. This includes not just the external API that is to be presented to the outside world but also “private” code.
- Whitebox testing (examining the code being tested when the tests are being written) is preferred. Blackbox testing (testing only the published user interface) is not complete enough to make sure all boundary and edge cases are tested.
- Make sure all possible values are tested including invalid ones. This makes sure that not only all valid values are acceptable but also that improper values are handled correctly.
- Exhaust as many code paths as possible. Test where branching occurs and thus tailor input to make sure as many different paths through the code are taken.
- Add an explicit test for any bugs discovered for the tested code. This will make sure that the error does not crop up again if the code is changed in the future.
- Make sure to clean up after your tests (such as close and remove all temporary files).
- If a test is dependent on a specific condition of the operating system then verify the condition already exists before attempting the test.
- Import as few modules as possible and do it as soon as possible. This minimizes external dependencies of tests and also minimizes possible anomalous behavior from side-effects of importing a module.

- Try to maximize code reuse. On occasion, tests will vary by something as small as what type of input is used. Minimize code duplication by subclassing a basic test class with a class that specifies the input:

```
class TestFuncAcceptsSequences (unittest.TestCase) :

    func = mySuperWhammyFunction

    def test_func(self) :
        self.func(self.arg)

class AcceptLists (TestFuncAcceptsSequences) :
    arg = [1, 2, 3]

class AcceptStrings (TestFuncAcceptsSequences) :
    arg = 'abc'

class AcceptTuples (TestFuncAcceptsSequences) :
    arg = (1, 2, 3)
```

See Also:

**Test Driven Development** A book by Kent Beck on writing tests before code.

## 25.5.2 Running tests using the command-line interface

The `test.regrtest` module can be run as a script to drive Python's regression test suite, thanks to the `-m` option: **python -m test.regrtest**. Running the script by itself automatically starts running all regression tests in the `test` package. It does this by finding all modules in the package whose name starts with `test_`, importing them, and executing the function `test_main()` if present. The names of tests to execute may also be passed to the script. Specifying a single regression test (**python -m test.regrtest test\_spam**) will minimize output and only print whether the test passed or failed and thus minimize output.

Running `test.regrtest` directly allows what resources are available for tests to use to be set. You do this by using the `-u` command-line option. Specifying `all` as the value for the `-u` option enables all possible resources: **python -m test -uall**. If all but one resource is desired (a more common case), a comma-separated list of resources that are not desired may be listed after `all`. The command **python -m test.regrtest -uall,-audio,-largefile** will run `test.regrtest` with all resources except the `audio` and `largefile` resources. For a list of all resources and more command-line options, run **python -m test.regrtest -h**.

Some other ways to execute the regression tests depend on what platform the tests are being executed on. On Unix, you can run **make test** at the top-level directory where Python was built. On Windows, executing **rt.bat** from your `PCBuild` directory will run all regression tests.

## 25.6 test.test\_support — Utility functions for tests

---

**Note:** The `test.test_support` module has been renamed to `test.support` in Python 3.x.

---

The `test.test_support` module provides support for Python's regression tests.

This module defines the following exceptions:

**exception test.test\_support.TestFailed**

Exception to be raised when a test fails. This is deprecated in favor of `unittest`-based tests and `unittest.TestCase`'s assertion methods.

### exception `test.test_support.ResourceDenied`

Subclass of `unittest.SkipTest`. Raised when a resource (such as a network connection) is not available. Raised by the `requires()` function.

The `test.test_support` module defines the following constants:

#### `test.test_support.verbose`

`True` when verbose output is enabled. Should be checked when more detailed information is desired about a running test. `verbose` is set by `test.regrtest`.

#### `test.test_support.have_unicode`

`True` when Unicode support is available.

#### `test.test_support.is_jython`

`True` if the running interpreter is Jython.

#### `test.test_support.TESTFN`

Set to a name that is safe to use as the name of a temporary file. Any temporary file that is created should be closed and unlinked (removed).

The `test.test_support` module defines the following functions:

#### `test.test_support.forget(module_name)`

Remove the module named `module_name` from `sys.modules` and delete any byte-compiled files of the module.

#### `test.test_support.is_resource_enabled(resource)`

Return `True` if `resource` is enabled and available. The list of available resources is only set when `test.regrtest` is executing the tests.

#### `test.test_support.requires(resource[, msg])`

Raise `ResourceDenied` if `resource` is not available. `msg` is the argument to `ResourceDenied` if it is raised. Always returns `True` if called by a function whose `__name__` is `'__main__'`. Used when tests are executed by `test.regrtest`.

#### `test.test_support.findfile(filename)`

Return the path to the file named `filename`. If no match is found `filename` is returned. This does not equal a failure since it could be the path to the file.

#### `test.test_support.run_unittest(*classes)`

Execute `unittest.TestCase` subclasses passed to the function. The function scans the classes for methods starting with the prefix `test_` and executes the tests individually.

It is also legal to pass strings as parameters; these should be keys in `sys.modules`. Each associated module will be scanned by `unittest.TestLoader.loadTestsFromModule()`. This is usually seen in the following `test_main()` function:

```
def test_main():
    test_support.run_unittest(__name__)
```

This will run all tests defined in the named module.

#### `test.test_support.check_warnings(*filters, quiet=True)`

A convenience wrapper for `warnings.catch_warnings()` that makes it easier to test that a warning was correctly raised. It is approximately equivalent to calling `warnings.catch_warnings(record=True)` with `warnings.simplefilter()` set to `always` and with the option to automatically validate the results that are recorded.

`check_warnings` accepts 2-tuples of the form `("message regexp", WarningCategory)` as positional arguments. If one or more `filters` are provided, or if the optional keyword argument `quiet` is `False`, it checks to make sure the warnings are as expected: each specified filter must match at least one of the warnings

raised by the enclosed code or the test fails, and if any warnings are raised that do not match any of the specified filters the test fails. To disable the first of these checks, set *quiet* to `True`.

If no arguments are specified, it defaults to:

```
check_warnings((" ", Warning), quiet=True)
```

In this case all warnings are caught and no errors are raised.

On entry to the context manager, a `WarningRecorder` instance is returned. The underlying warnings list from `catch_warnings()` is available via the recorder object's `warnings` attribute. As a convenience, the attributes of the object representing the most recent warning can also be accessed directly through the recorder object (see example below). If no warning has been raised, then any of the attributes that would otherwise be expected on an object representing a warning will return `None`.

The recorder object also has a `reset()` method, which clears the warnings list.

The context manager is designed to be used like this:

```
with check_warnings(("assertion is always true", SyntaxWarning),
                   (" ", UserWarning)):
    exec('assert(False, "Hey!")')
    warnings.warn(UserWarning("Hide me!"))
```

In this case if either warning was not raised, or some other warning was raised, `check_warnings()` would raise an error.

When a test needs to look more deeply into the warnings, rather than just checking whether or not they occurred, code like this can be used:

```
with check_warnings(quiet=True) as w:
    warnings.warn("foo")
    assert str(w.args[0]) == "foo"
    warnings.warn("bar")
    assert str(w.args[0]) == "bar"
    assert str(w.warnings[0].args[0]) == "foo"
    assert str(w.warnings[1].args[0]) == "bar"
    w.reset()
    assert len(w.warnings) == 0
```

Here all warnings will be caught, and the test code tests the captured warnings directly. New in version 2.6.Changed in version 2.7: New optional arguments *filters* and *quiet*.

```
test.test_support.check_py3k_warnings(*filters, quiet=False)
```

Similar to `check_warnings()`, but for Python 3 compatibility warnings. If `sys.py3kwarning == 1`, it checks if the warning is effectively raised. If `sys.py3kwarning == 0`, it checks that no warning is raised. It accepts 2-tuples of the form `("message regexp", WarningCategory)` as positional arguments. When the optional keyword argument *quiet* is `True`, it does not fail if a filter catches nothing. Without arguments, it defaults to:

```
check_py3k_warnings((" ", DeprecationWarning), quiet=False)
```

New in version 2.7.

```
test.test_support.captured_stdout()
```

This is a context manager that runs the `with` statement body using a `StringIO.StringIO` object as `sys.stdout`. That object can be retrieved using the `as` clause of the `with` statement.

Example use:

```
with captured_stdout() as s:
    print "hello"
assert s.getvalue() == "hello\n"
```

New in version 2.6.

`test.test_support.import_module(name, deprecated=False)`

This function imports and returns the named module. Unlike a normal import, this function raises `unittest.SkipTest` if the module cannot be imported.

Module and package deprecation messages are suppressed during this import if *deprecated* is `True`. New in version 2.7.

`test.test_support.import_fresh_module(name, fresh=(), blocked=(), deprecated=False)`

This function imports and returns a fresh copy of the named Python module by removing the named module from `sys.modules` before doing the import. Note that unlike `reload()`, the original module is not affected by this operation.

*fresh* is an iterable of additional module names that are also removed from the `sys.modules` cache before doing the import.

*blocked* is an iterable of module names that are replaced with 0 in the module cache during the import to ensure that attempts to import them raise `ImportError`.

The named module and any modules named in the *fresh* and *blocked* parameters are saved before starting the import and then reinserted into `sys.modules` when the fresh import is complete.

Module and package deprecation messages are suppressed during this import if *deprecated* is `True`.

This function will raise `unittest.SkipTest` if the named module cannot be imported.

Example use:

```
# Get copies of the warnings module for testing without
# affecting the version being used by the rest of the test suite
# One copy uses the C implementation, the other is forced to use
# the pure Python fallback implementation
py_warnings = import_fresh_module('warnings', blocked=['_warnings'])
c_warnings = import_fresh_module('warnings', fresh=['_warnings'])
```

New in version 2.7.

The `test.test_support` module defines the following classes:

**class** `test.test_support.TransientResource` (*exc*[, *\*\*kwargs* ])

Instances are a context manager that raises `ResourceDenied` if the specified exception type is raised. Any keyword arguments are treated as attribute/value pairs to be compared against any exception raised within the `with` statement. Only if all pairs match properly against attributes on the exception is `ResourceDenied` raised. New in version 2.6.

**class** `test.test_support.EnvironmentVarGuard`

Class used to temporarily set or unset environment variables. Instances can be used as a context manager and have a complete dictionary interface for querying/modifying the underlying `os.environ`. After exit from the context manager all changes to environment variables done through this instance will be rolled back. New in version 2.6. Changed in version 2.7: Added dictionary interface.

`EnvironmentVarGuard.set` (*envvar*, *value*)

Temporarily set the environment variable *envvar* to the value of *value*.

`EnvironmentVarGuard.unset(envvar)`

Temporarily unset the environment variable `envvar`.

**class** `test.test_support.WarningsRecorder`

Class used to record warnings for unit tests. See documentation of `check_warnings()` above for more details. New in version 2.6.



# DEBUGGING AND PROFILING

These libraries help you with Python development: the debugger enables you to step through code, analyze stack frames and set breakpoints etc., and the profilers run code and give you a detailed breakdown of execution times, allowing you to identify bottlenecks in your programs.

## 26.1 `bdb` — Debugger framework

**Source code:** [Lib/bdb.py](#)

---

The `bdb` module handles basic debugger functions, like setting breakpoints or managing execution via the debugger.

The following exception is defined:

**exception** `bdb.BdbQuit`

Exception raised by the `Bdb` class for quitting the debugger.

The `bdb` module also defines two classes:

**class** `bdb.Breakpoint` (*self, file, line, temporary=0, cond=None, funcname=None*)

This class implements temporary breakpoints, ignore counts, disabling and (re-)enabling, and conditionals.

Breakpoints are indexed by number through a list called `bdbnumber` and by (`file`, `line`) pairs through `bplist`. The former points to a single instance of class `Breakpoint`. The latter points to a list of such instances since there may be more than one breakpoint per line.

When creating a breakpoint, its associated filename should be in canonical form. If a `funcname` is defined, a breakpoint hit will be counted when the first line of that function is executed. A conditional breakpoint always counts a hit.

`Breakpoint` instances have the following methods:

**deleteMe** ()

Delete the breakpoint from the list associated to a file/line. If it is the last breakpoint in that position, it also deletes the entry for the file/line.

**enable** ()

Mark the breakpoint as enabled.

**disable** ()

Mark the breakpoint as disabled.

**pprint** ([*out*])

Print all the information about the breakpoint:

- The breakpoint number.
- If it is temporary or not.
- Its file,line position.
- The condition that causes a break.
- If it must be ignored the next N times.
- The breakpoint hit count.

**class** `bdb.Bdb` (*skip=None*)

The `Bdb` class acts as a generic Python debugger base class.

This class takes care of the details of the trace facility; a derived class should implement user interaction. The standard debugger class (`pdb.Pdb`) is an example.

The *skip* argument, if given, must be an iterable of glob-style module name patterns. The debugger will not step into frames that originate in a module that matches one of these patterns. Whether a frame is considered to originate in a certain module is determined by the `__name__` in the frame `globals`. New in version 2.7: The *skip* argument. The following methods of `Bdb` normally don't need to be overridden.

**canonic** (*filename*)

Auxiliary method for getting a filename in a canonical form, that is, as a case-normalized (on case-insensitive filesystems) absolute path, stripped of surrounding angle brackets.

**reset** ()

Set the `botframe`, `stopframe`, `returnframe` and `quitting` attributes with values ready to start debugging.

**trace\_dispatch** (*frame, event, arg*)

This function is installed as the trace function of debugged frames. Its return value is the new trace function (in most cases, that is, itself).

The default implementation decides how to dispatch a frame, depending on the type of event (passed as a string) that is about to be executed. *event* can be one of the following:

- "line": A new line of code is going to be executed.
- "call": A function is about to be called, or another code block entered.
- "return": A function or other code block is about to return.
- "exception": An exception has occurred.
- "c\_call": A C function is about to be called.
- "c\_return": A C function has returned.
- "c\_exception": A C function has raised an exception.

For the Python events, specialized functions (see below) are called. For the C events, no action is taken.

The *arg* parameter depends on the previous event.

See the documentation for `sys.settrace()` for more information on the trace function. For more information on code and frame objects, refer to *types*.

**dispatch\_line** (*frame*)

If the debugger should stop on the current line, invoke the `user_line()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the `Bdb.quitting` flag is set (which can be set from `user_line()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

**dispatch\_call** (*frame*, *arg*)

If the debugger should stop on this function call, invoke the `user_call()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the `Bdb.quitting` flag is set (which can be set from `user_call()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

**dispatch\_return** (*frame*, *arg*)

If the debugger should stop on this function return, invoke the `user_return()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the `Bdb.quitting` flag is set (which can be set from `user_return()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

**dispatch\_exception** (*frame*, *arg*)

If the debugger should stop at this exception, invokes the `user_exception()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the `Bdb.quitting` flag is set (which can be set from `user_exception()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

Normally derived classes don't override the following methods, but they may if they want to redefine the definition of stopping and breakpoints.

**stop\_here** (*frame*)

This method checks if the *frame* is somewhere below `botframe` in the call stack. `botframe` is the frame in which debugging started.

**break\_here** (*frame*)

This method checks if there is a breakpoint in the filename and line belonging to *frame* or, at least, in the current function. If the breakpoint is a temporary one, this method deletes it.

**break\_anywhere** (*frame*)

This method checks if there is a breakpoint in the filename of the current frame.

Derived classes should override these methods to gain control over debugger operation.

**user\_call** (*frame*, *argument\_list*)

This method is called from `dispatch_call()` when there is the possibility that a break might be necessary anywhere inside the called function.

**user\_line** (*frame*)

This method is called from `dispatch_line()` when either `stop_here()` or `break_here()` yields True.

**user\_return** (*frame*, *return\_value*)

This method is called from `dispatch_return()` when `stop_here()` yields True.

**user\_exception** (*frame*, *exc\_info*)

This method is called from `dispatch_exception()` when `stop_here()` yields True.

**do\_clear** (*arg*)

Handle how a breakpoint must be removed when it is a temporary one.

This method must be implemented by derived classes.

Derived classes and clients can call the following methods to affect the stepping state.

**set\_step** ()

Stop after one line of code.

**set\_next** (*frame*)

Stop on the next line in or below the given frame.

**set\_return** (*frame*)

Stop when returning from the given frame.

**set\_until** (*frame*)

Stop when the line with the line no greater than the current one is reached or when returning from current frame

**set\_trace** ([*frame*])

Start debugging from *frame*. If *frame* is not specified, debugging starts from caller's frame.

**set\_continue** ()

Stop only at breakpoints or when finished. If there are no breakpoints, set the system trace function to None.

**set\_quit** ()

Set the `quitting` attribute to True. This raises `BdbQuit` in the next call to one of the `dispatch_*()` methods.

Derived classes and clients can call the following methods to manipulate breakpoints. These methods return a string containing an error message if something went wrong, or None if all is well.

**set\_break** (*filename*, *lineno*, *temporary=0*, *cond=None*, *funcname=None*)

Set a new breakpoint. If the *lineno* line doesn't exist for the *filename* passed as argument, return an error message. The *filename* should be in canonical form, as described in the `canonic()` method.

**clear\_break** (*filename*, *lineno*)

Delete the breakpoints in *filename* and *lineno*. If none were set, an error message is returned.

**clear\_bpbynumber** (*arg*)

Delete the breakpoint which has the index *arg* in the `Breakpoint.bpbynumber`. If *arg* is not numeric or out of range, return an error message.

**clear\_all\_file\_breaks** (*filename*)

Delete all breakpoints in *filename*. If none were set, an error message is returned.

**clear\_all\_breaks** ()

Delete all existing breakpoints.

**get\_break** (*filename*, *lineno*)

Check if there is a breakpoint for *lineno* of *filename*.

**get\_breaks** (*filename*, *lineno*)

Return all breakpoints for *lineno* in *filename*, or an empty list if none are set.

**get\_file\_breaks** (*filename*)

Return all breakpoints in *filename*, or an empty list if none are set.

**get\_all\_breaks** ()

Return all breakpoints that are set.

Derived classes and clients can call the following methods to get a data structure representing a stack trace.

**get\_stack** (*f*, *t*)

Get a list of records for a frame and all higher (calling) and lower frames, and the size of the higher part.

**format\_stack\_entry** (*frame\_lineno* [, *lprefix*=': '])

Return a string with information about a stack entry, identified by a (*frame*, *lineno*) tuple:

- The canonical form of the filename which contains the frame.
- The function name, or "<lambda>".
- The input arguments.

- The return value.
- The line of code (if it exists).

The following two methods can be called by clients to use a debugger to debug a *statement*, given as a string.

**run** (*cmd* [, *globals* [, *locals* ] ])

Debug a statement executed via the `exec` statement. *globals* defaults to `__main__.__dict__`, *locals* defaults to *globals*.

**runeval** (*expr* [, *globals* [, *locals* ] ])

Debug an expression executed via the `eval()` function. *globals* and *locals* have the same meaning as in `run()`.

**runctx** (*cmd*, *globals*, *locals*)

For backwards compatibility. Calls the `run()` method.

**runcall** (*func*, *\*args*, *\*\*kwds*)

Debug a single function call, and return its result.

Finally, the module defines the following functions:

`bdb.checkfuncname` (*b*, *frame*)

Check whether we should break here, depending on the way the breakpoint *b* was set.

If it was set via line number, it checks if `b.line` is the same as the one in the frame also passed as argument. If the breakpoint was set via function name, we have to check we are in the right frame (the right function) and if we are in its first executable line.

`bdb.effective` (*file*, *line*, *frame*)

Determine if there is an effective (active) breakpoint at this line of code. Return a tuple of the breakpoint and a boolean that indicates if it is ok to delete a temporary breakpoint. Return `(None, None)` if there is no matching breakpoint.

`bdb.set_trace` ()

Start debugging with a `Bdb` instance from caller's frame.

## 26.2 pdb — The Python Debugger

The module `pdb` defines an interactive source code debugger for Python programs. It supports setting (conditional) breakpoints and single stepping at the source line level, inspection of stack frames, source code listing, and evaluation of arbitrary Python code in the context of any stack frame. It also supports post-mortem debugging and can be called under program control.

The debugger is extensible — it is actually defined as the class `Pdb`. This is currently undocumented but easily understood by reading the source. The extension interface uses the modules `bdb` and `cmd`.

The debugger's prompt is `(Pdb)`. Typical usage to run a program under control of the debugger is:

```
>>> import pdb
>>> import mymodule
>>> pdb.run('mymodule.test()')
> <string>(0)?()
(Pdb) continue
> <string>(1)?()
(Pdb) continue
NameError: 'spam'
> <string>(1)?()
(Pdb)
```

`pdb.py` can also be invoked as a script to debug other scripts. For example:

```
python -m pdb myscript.py
```

When invoked as a script, `pdb` will automatically enter post-mortem debugging if the program being debugged exits abnormally. After post-mortem debugging (or after normal exit of the program), `pdb` will restart the program. Automatic restarting preserves `pdb`'s state (such as breakpoints) and in most cases is more useful than quitting the debugger upon program's exit. New in version 2.4: Restarting post-mortem behavior added. The typical usage to break into the debugger from a running program is to insert

```
import pdb; pdb.set_trace()
```

at the location you want to break into the debugger. You can then step through the code following this statement, and continue running without the debugger using the `c` command.

The typical usage to inspect a crashed program is:

```
>>> import pdb
>>> import mymodule
>>> mymodule.test()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "./mymodule.py", line 4, in test
    test2()
  File "./mymodule.py", line 3, in test2
    print spam
NameError: spam
>>> pdb.pm()
> ./mymodule.py(3)test2()
-> print spam
(Pdb)
```

The module defines the following functions; each enters the debugger in a slightly different way:

`pdb.run` (*statement* [, *globals* [, *locals* ]])

Execute the *statement* (given as a string) under debugger control. The debugger prompt appears before any code is executed; you can set breakpoints and type `continue`, or you can step through the statement using `step` or `next` (all these commands are explained below). The optional *globals* and *locals* arguments specify the environment in which the code is executed; by default the dictionary of the module `__main__` is used. (See the explanation of the `exec` statement or the `eval()` built-in function.)

`pdb.runeval` (*expression* [, *globals* [, *locals* ]])

Evaluate the *expression* (given as a string) under debugger control. When `runeval()` returns, it returns the value of the expression. Otherwise this function is similar to `run()`.

`pdb.runcall` (*function* [, *argument*, ...])

Call the *function* (a function or method object, not a string) with the given arguments. When `runcall()` returns, it returns whatever the function call returned. The debugger prompt appears as soon as the function is entered.

`pdb.set_trace` ()

Enter the debugger at the calling stack frame. This is useful to hard-code a breakpoint at a given point in a program, even if the code is not otherwise being debugged (e.g. when an assertion fails).

`pdb.post_mortem` ([*traceback*])

Enter post-mortem debugging of the given *traceback* object. If no *traceback* is given, it uses the one of the exception that is currently being handled (an exception must be being handled if the default is to be used).

`pdb.pm` ()

Enter post-mortem debugging of the traceback found in `sys.last_traceback`.

The `run*` functions and `set_trace()` are aliases for instantiating the `Pdb` class and calling the method of the same name. If you want to access further features, you have to do this yourself:

```
class pdb.Pdb(completekey='tab', stdin=None, stdout=None, skip=None)
```

`Pdb` is the debugger class.

The *completekey*, *stdin* and *stdout* arguments are passed to the underlying `cmd.Cmd` class; see the description there.

The *skip* argument, if given, must be an iterable of glob-style module name patterns. The debugger will not step into frames that originate in a module that matches one of these patterns.<sup>1</sup>

Example call to enable tracing with *skip*:

```
import pdb; pdb.Pdb(skip=['django.*']).set_trace()
```

New in version 2.7: The *skip* argument.

```
run (statement [, globals [, locals ]])
runeval (expression [, globals [, locals ]])
runcall (function [, argument, ... ])
set_trace ()
```

See the documentation for the functions explained above.

## 26.3 Debugger Commands

The debugger recognizes the following commands. Most commands can be abbreviated to one or two letters; e.g. `h(elp)` means that either `h` or `help` can be used to enter the help command (but not `he` or `hel`, nor `H` or `Help` or `HELP`). Arguments to commands must be separated by whitespace (spaces or tabs). Optional arguments are enclosed in square brackets (`[]`) in the command syntax; the square brackets must not be typed. Alternatives in the command syntax are separated by a vertical bar (`|`).

Entering a blank line repeats the last command entered. Exception: if the last command was a `list` command, the next 11 lines are listed.

Commands that the debugger doesn't recognize are assumed to be Python statements and are executed in the context of the program being debugged. Python statements can also be prefixed with an exclamation point (`!`). This is a powerful way to inspect the program being debugged; it is even possible to change a variable or call a function. When an exception occurs in such a statement, the exception name is printed but the debugger's state is not changed.

Multiple commands may be entered on a single line, separated by `;;`. (A single `;` is not used as it is the separator for multiple commands in a line that is passed to the Python parser.) No intelligence is applied to separating the commands; the input is split at the first `;;` pair, even if it is in the middle of a quoted string.

The debugger supports aliases. Aliases can have parameters which allows one a certain level of adaptability to the context under examination.

If a file `.pdbrc` exists in the user's home directory or in the current directory, it is read in and executed as if it had been typed at the debugger prompt. This is particularly useful for aliases. If both files exist, the one in the home directory is read first and aliases defined there can be overridden by the local file.

**h(elp) [command]** Without argument, print the list of available commands. With a *command* as argument, print help about that command. `help pdb` displays the full documentation file; if the environment variable `PAGER` is defined, the file is piped through that command instead. Since the *command* argument must be an identifier, `help exec` must be entered to get help on the `!` command.

<sup>1</sup> Whether a frame is considered to originate in a certain module is determined by the `__name__` in the frame `globals`.

**w(here)** Print a stack trace, with the most recent frame at the bottom. An arrow indicates the current frame, which determines the context of most commands.

**d(own)** Move the current frame one level down in the stack trace (to a newer frame).

**u(p)** Move the current frame one level up in the stack trace (to an older frame).

**b(reak)** `[[filename:]lineno | function[, condition]]` With a *lineno* argument, set a break there in the current file. With a *function* argument, set a break at the first executable statement within that function. The line number may be prefixed with a filename and a colon, to specify a breakpoint in another file (probably one that hasn't been loaded yet). The file is searched on `sys.path`. Note that each breakpoint is assigned a number to which all the other breakpoint commands refer.

If a second argument is present, it is an expression which must evaluate to true before the breakpoint is honored.

Without argument, list all breaks, including for each breakpoint, the number of times that breakpoint has been hit, the current ignore count, and the associated condition if any.

**tbreak** `[[filename:]lineno | function[, condition]]` Temporary breakpoint, which is removed automatically when it is first hit. The arguments are the same as `break`.

**cl(ear)** `[filename:lineno | bnumber [bnumber ...]]` With a `filename:lineno` argument, clear all the breakpoints at this line. With a space separated list of breakpoint numbers, clear those breakpoints. Without argument, clear all breaks (but first ask confirmation).

**disable** `[bnumber [bnumber ...]]` Disables the breakpoints given as a space separated list of breakpoint numbers. Disabling a breakpoint means it cannot cause the program to stop execution, but unlike clearing a breakpoint, it remains in the list of breakpoints and can be (re-)enabled.

**enable** `[bnumber [bnumber ...]]` Enables the breakpoints specified.

**ignore** `bnumber [count]` Sets the ignore count for the given breakpoint number. If `count` is omitted, the ignore count is set to 0. A breakpoint becomes active when the ignore count is zero. When non-zero, the count is decremented each time the breakpoint is reached and the breakpoint is not disabled and any associated condition evaluates to true.

**condition** `bnumber [condition]` Condition is an expression which must evaluate to true before the breakpoint is honored. If condition is absent, any existing condition is removed; i.e., the breakpoint is made unconditional.

**commands** `[bnumber]` Specify a list of commands for breakpoint number *bnumber*. The commands themselves appear on the following lines. Type a line containing just 'end' to terminate the commands. An example:

```
(Pdb) commands 1
(com) print some_variable
(com) end
(Pdb)
```

To remove all commands from a breakpoint, type `commands` and follow it immediately with `end`; that is, give no commands.

With no *bnumber* argument, `commands` refers to the last breakpoint set.

You can use breakpoint commands to start your program up again. Simply use the `continue` command, or `step`, or any other command that resumes execution.

Specifying any command resuming execution (currently `continue`, `step`, `next`, `return`, `jump`, `quit` and their abbreviations) terminates the command list (as if that command was immediately followed by `end`). This is because any time you resume execution (even with a simple `next` or `step`), you may encounter another breakpoint—which could have its own command list, leading to ambiguities about which list to execute.

If you use the 'silent' command in the command list, the usual message about stopping at a breakpoint is not printed. This may be desirable for breakpoints that are to print a specific message and then continue. If none of the other commands print anything, you see no sign that the breakpoint was reached. New in version 2.5.

**s(step)** Execute the current line, stop at the first possible occasion (either in a function that is called or on the next line in the current function).

**n(ext)** Continue execution until the next line in the current function is reached or it returns. (The difference between `next` and `step` is that `step` stops inside a called function, while `next` executes called functions at (nearly) full speed, only stopping at the next line in the current function.)

**unt(il)** Continue execution until the line with the line number greater than the current one is reached or when returning from current frame. New in version 2.6.

**r(eturn)** Continue execution until the current function returns.

**c(ontinue)** Continue execution, only stop when a breakpoint is encountered.

**j(ump) lineno** Set the next line that will be executed. Only available in the bottom-most frame. This lets you jump back and execute code again, or jump forward to skip code that you don't want to run.

It should be noted that not all jumps are allowed — for instance it is not possible to jump into the middle of a `for` loop or out of a `finally` clause.

**l(list) [first[, last]]** List source code for the current file. Without arguments, list 11 lines around the current line or continue the previous listing. With one argument, list 11 lines around at that line. With two arguments, list the given range; if the second argument is less than the first, it is interpreted as a count.

**a(rgs)** Print the argument list of the current function.

**p expression** Evaluate the *expression* in the current context and print its value.

---

**Note:** `print` can also be used, but is not a debugger command — this executes the Python `print` statement.

---

**pp expression** Like the `p` command, except the value of the expression is pretty-printed using the `pprint` module.

**alias [name [command]]** Creates an alias called *name* that executes *command*. The command must *not* be enclosed in quotes. Replaceable parameters can be indicated by `%1`, `%2`, and so on, while `.*` is replaced by all the parameters. If no command is given, the current alias for *name* is shown. If no arguments are given, all aliases are listed.

Aliases may be nested and can contain anything that can be legally typed at the `pdb` prompt. Note that internal `pdb` commands *can* be overridden by aliases. Such a command is then hidden until the alias is removed. Aliasing is recursively applied to the first word of the command line; all other words in the line are left alone.

As an example, here are two useful aliases (especially when placed in the `.pdbrc` file):

```
#Print instance variables (usage "pi classInst")
alias pi for k in %1.__dict__.keys(): print "%1.", k, "=", %1.__dict__[k]
#Print instance variables in self
alias ps pi self
```

**unalias name** Deletes the specified alias.

**[!]statement** Execute the (one-line) *statement* in the context of the current stack frame. The exclamation point can be omitted unless the first word of the statement resembles a debugger command. To set a global variable, you can prefix the assignment command with a `global` command on the same line, e.g.:

```
(Pdb) global list_options; list_options = ['-l']
(Pdb)
```

**run [args ...]** Restart the debugged Python program. If an argument is supplied, it is split with “`shlex`” and the result is used as the new `sys.argv`. History, breakpoints, actions and debugger options are preserved. “restart” is an alias for “run”. New in version 2.6.

**q(uit)** Quit from the debugger. The program being executed is aborted.

## 26.4 The Python Profilers

**Source code:** `Lib/profile.py` and `Lib/pstats.py`

---

### 26.4.1 Introduction to the profilers

A *profiler* is a program that describes the run time performance of a program, providing a variety of statistics. This documentation describes the profiler functionality provided in the modules `cProfile`, `profile` and `pstats`. This profiler provides *deterministic profiling* of Python programs. It also provides a series of report generation tools to allow users to rapidly examine the results of a profile operation.

The Python standard library provides three different profilers:

1. `cProfile` is recommended for most users; it's a C extension with reasonable overhead that makes it suitable for profiling long-running programs. Based on `lsprof`, contributed by Brett Rosen and Ted Czotter. New in version 2.5.
2. `profile`, a pure Python module whose interface is imitated by `cProfile`. Adds significant overhead to profiled programs. If you're trying to extend the profiler in some way, the task might be easier with this module. Changed in version 2.4: Now also reports the time spent in calls to built-in functions and methods.
3. `hotshot` was an experimental C module that focused on minimizing the overhead of profiling, at the expense of longer data post-processing times. It is no longer maintained and may be dropped in a future version of Python. Changed in version 2.5: The results should be more meaningful than in the past: the timing core contained a critical bug.

The `profile` and `cProfile` modules export the same interface, so they are mostly interchangeable; `cProfile` has a much lower overhead but is newer and might not be available on all systems. `cProfile` is really a compatibility layer on top of the internal `_lsprof` module. The `hotshot` module is reserved for specialized usage.

### 26.4.2 Instant User's Manual

This section is provided for users that “don't want to read the manual.” It provides a very brief overview, and allows a user to rapidly perform profiling on an existing application.

To profile an application with a main entry point of `foo()`, you would add the following to your module:

```
import cProfile
cProfile.run('foo()')
```

(Use `profile` instead of `cProfile` if the latter is not available on your system.)

The above action would cause `foo()` to be run, and a series of informative lines (the profile) to be printed. The above approach is most useful when working with the interpreter. If you would like to save the results of a profile into a file for later examination, you can supply a file name as the second argument to the `run()` function:

```
import cProfile
cProfile.run('foo()', 'fooprof')
```

The file `cProfile.py` can also be invoked as a script to profile another script. For example:

```
python -m cProfile myscript.py
```

`cProfile.py` accepts two optional arguments on the command line:

```
cProfile.py [-o output_file] [-s sort_order]
```

`-s` only applies to standard output (`-o` is not supplied). Look in the `Stats` documentation for valid sort values.

When you wish to review the profile, you should use the methods in the `pstats` module. Typically you would load the statistics data as follows:

```
import pstats
p = pstats.Stats('fooprof')
```

The class `Stats` (the above code just created an instance of this class) has a variety of methods for manipulating and printing the data that was just read into `p`. When you ran `cProfile.run()` above, what was printed was the result of three method calls:

```
p.strip_dirs().sort_stats(-1).print_stats()
```

The first method removed the extraneous path from all the module names. The second method sorted all the entries according to the standard module/line/name string that is printed. The third method printed out all the statistics. You might try the following sort calls:

```
p.sort_stats('name')
p.print_stats()
```

The first call will actually sort the list by function name, and the second call will print out the statistics. The following are some interesting calls to experiment with:

```
p.sort_stats('cumulative').print_stats(10)
```

This sorts the profile by cumulative time in a function, and then only prints the ten most significant lines. If you want to understand what algorithms are taking time, the above line is what you would use.

If you were looking to see what functions were looping a lot, and taking a lot of time, you would do:

```
p.sort_stats('time').print_stats(10)
```

to sort according to time spent within each function, and then print the statistics for the top ten functions.

You might also try:

```
p.sort_stats('file').print_stats('__init__')
```

This will sort all the statistics by file name, and then print out statistics for only the class init methods (since they are spelled with `__init__` in them). As one final example, you could try:

```
p.sort_stats('time', 'cum').print_stats(.5, 'init')
```

This line sorts statistics with a primary key of time, and a secondary key of cumulative time, and then prints out some of the statistics. To be specific, the list is first culled down to 50% (re: `.5`) of its original size, then only lines containing `init` are maintained, and that sub-sub-list is printed.

If you wondered what functions called the above functions, you could now (`p` is still sorted according to the last criteria) do:

```
p.print_callers(.5, 'init')
```

and you would get a list of callers for each of the listed functions.

If you want more functionality, you're going to have to read the manual, or guess what the following functions do:

```
p.print_callees()
p.add('fooprof')
```

Invoked as a script, the `pstats` module is a statistics browser for reading and examining profile dumps. It has a simple line-oriented interface (implemented using `cmd`) and interactive help.

### 26.4.3 What Is Deterministic Profiling?

*Deterministic profiling* is meant to reflect the fact that all *function call*, *function return*, and *exception* events are monitored, and precise timings are made for the intervals between these events (during which time the user’s code is executing). In contrast, *statistical profiling* (which is not done by this module) randomly samples the effective instruction pointer, and deduces where time is being spent. The latter technique traditionally involves less overhead (as the code does not need to be instrumented), but provides only relative indications of where time is being spent.

In Python, since there is an interpreter active during execution, the presence of instrumented code is not required to do deterministic profiling. Python automatically provides a *hook* (optional callback) for each event. In addition, the interpreted nature of Python tends to add so much overhead to execution, that deterministic profiling tends to only add small processing overhead in typical applications. The result is that deterministic profiling is not that expensive, yet provides extensive run time statistics about the execution of a Python program.

Call count statistics can be used to identify bugs in code (surprising counts), and to identify possible inline-expansion points (high call counts). Internal time statistics can be used to identify “hot loops” that should be carefully optimized. Cumulative time statistics should be used to identify high level errors in the selection of algorithms. Note that the unusual handling of cumulative times in this profiler allows statistics for recursive implementations of algorithms to be directly compared to iterative implementations.

### 26.4.4 Reference Manual – `profile` and `cProfile`

The primary entry point for the profiler is the global function `profile.run()` (resp. `cProfile.run()`). It is typically used to create any profile information. The reports are formatted and printed using methods of the class `pstats.Stats`. The following is a description of all of these standard entry points and functions. For a more in-depth view of some of the code, consider reading the later section on Profiler Extensions, which includes discussion of how to derive “better” profilers from the classes presented, or reading the source code for these modules.

`cProfile.run(command[, filename ])`

This function takes a single argument that can be passed to the `exec` statement, and an optional file name. In all cases this routine attempts to `exec` its first argument, and gather profiling statistics from the execution. If no file name is present, then this function automatically prints a simple profiling report, sorted by the standard name string (file/line/function-name) that is presented in each line. The following is a typical output from such a call:

```
2706 function calls (2004 primitive calls) in 4.504 CPU seconds

Ordered by: standard name

ncalls  tottime  percall  cumtime  percall  filename:lineno(function)
      2    0.006    0.003    0.953    0.477  pobject.py:75(save_objects)
    43/3    0.533    0.012    0.749    0.250  pobject.py:99(evaluate)
...

```

The first line indicates that 2706 calls were monitored. Of those calls, 2004 were *primitive*. We define *primitive* to mean that the call was not induced via recursion. The next line: `Ordered by: standard name`, indicates that the text string in the far right column was used to sort the output. The column headings include:

**ncalls** for the number of calls,

**tottime** for the total time spent in the given function (and excluding time made in calls to sub-functions),

**percall** is the quotient of `tottime` divided by `ncalls`

**cumtime** is the total time spent in this and all subfunctions (from invocation till exit). This figure is accurate *even* for recursive functions.

**percall** is the quotient of `cumtime` divided by primitive calls

**filename:lineno(function)** provides the respective data of each function

When there are two numbers in the first column (for example, 43/3), then the latter is the number of primitive calls, and the former is the actual number of calls. Note that when the function does not recurse, these two values are the same, and only the single figure is printed.

`cProfile.runctx(command, globals, locals[, filename])`

This function is similar to `run()`, with added arguments to supply the globals and locals dictionaries for the *command* string.

Analysis of the profiler data is done using the `Stats` class.

---

**Note:** The `Stats` class is defined in the `pstats` module.

---

**class** `pstats.Stats(filename, stream=sys.stdout[, ...])`

This class constructor creates an instance of a “statistics object” from a *filename* (or set of filenames). `Stats` objects are manipulated by methods, in order to print useful reports. You may specify an alternate output stream by giving the keyword argument, *stream*.

The file selected by the above constructor must have been created by the corresponding version of `profile` or `cProfile`. To be specific, there is *no* file compatibility guaranteed with future versions of this profiler, and there is no compatibility with files produced by other profilers. If several files are provided, all the statistics for identical functions will be coalesced, so that an overall view of several processes can be considered in a single report. If additional files need to be combined with data in an existing `Stats` object, the `add()` method can be used. Changed in version 2.5: The *stream* parameter was added.

## The Stats Class

`Stats` objects have the following methods:

`Stats.strip_dirs()`

This method for the `Stats` class removes all leading path information from file names. It is very useful in reducing the size of the printout to fit within (close to) 80 columns. This method modifies the object, and the stripped information is lost. After performing a strip operation, the object is considered to have its entries in a “random” order, as it was just after object initialization and loading. If `strip_dirs()` causes two function names to be indistinguishable (they are on the same line of the same filename, and have the same function name), then the statistics for these two entries are accumulated into a single entry.

`Stats.add(filename[, ...])`

This method of the `Stats` class accumulates additional profiling information into the current profiling object. Its arguments should refer to filenames created by the corresponding version of `profile.run()` or `cProfile.run()`. Statistics for identically named (re: file, line, name) functions are automatically accumulated into single function statistics.

`Stats.dump_stats(filename)`

Save the data loaded into the `Stats` object to a file named *filename*. The file is created if it does not exist, and is overwritten if it already exists. This is equivalent to the method of the same name on the `profile.Profile` and `cProfile.Profile` classes. New in version 2.3.

`Stats.sort_stats(key[, ...])`

This method modifies the `Stats` object by sorting it according to the supplied criteria. The argument is typically a string identifying the basis of a sort (example: `'time'` or `'name'`).

When more than one key is provided, then additional keys are used as secondary criteria when there is equality in all keys selected before them. For example, `sort_stats('name', 'file')` will sort all the entries according to their function name, and resolve all ties (identical function names) by sorting by file name.

Abbreviations can be used for any key names, as long as the abbreviation is unambiguous. The following are the keys currently defined:

Valid Arg	Meaning
'calls'	call count
'cumulative'	cumulative time
'file'	file name
'module'	file name
'pcalls'	primitive call count
'line'	line number
'name'	function name
'nfl'	name/file/line
'stdname'	standard name
'time'	internal time

Note that all sorts on statistics are in descending order (placing most time consuming items first), where as name, file, and line number searches are in ascending order (alphabetical). The subtle distinction between 'nfl' and 'stdname' is that the standard name is a sort of the name as printed, which means that the embedded line numbers get compared in an odd way. For example, lines 3, 20, and 40 would (if the file names were the same) appear in the string order 20, 3 and 40. In contrast, 'nfl' does a numeric compare of the line numbers. In fact, `sort_stats('nfl')` is the same as `sort_stats('name', 'file', 'line')`.

For backward-compatibility reasons, the numeric arguments -1, 0, 1, and 2 are permitted. They are interpreted as 'stdname', 'calls', 'time', and 'cumulative' respectively. If this old style format (numeric) is used, only one sort key (the numeric key) will be used, and additional arguments will be silently ignored.

`Stats.reverse_order()`

This method for the `Stats` class reverses the ordering of the basic list within the object. Note that by default ascending vs descending order is properly selected based on the sort key of choice.

`Stats.print_stats([restriction, ...])`

This method for the `Stats` class prints out a report as described in the `profile.run()` definition.

The order of the printing is based on the last `sort_stats()` operation done on the object (subject to caveats in `add()` and `strip_dirs()`).

The arguments provided (if any) can be used to limit the list down to the significant entries. Initially, the list is taken to be the complete set of profiled functions. Each restriction is either an integer (to select a count of lines), or a decimal fraction between 0.0 and 1.0 inclusive (to select a percentage of lines), or a regular expression (to pattern match the standard name that is printed; as of Python 1.5b1, this uses the Perl-style regular expression syntax defined by the `re` module). If several restrictions are provided, then they are applied sequentially. For example:

```
print_stats(.1, 'foo:')
```

would first limit the printing to first 10% of list, and then only print functions that were part of filename `.*foo:.`. In contrast, the command:

```
print_stats('foo:', .1)
```

would limit the list to all functions having file names `.*foo:.`, and then proceed to only print the first 10% of them.

`Stats.print_callers([restriction, ...])`

This method for the `Stats` class prints a list of all functions that called each function in the profiled database. The ordering is identical to that provided by `print_stats()`, and the definition of the restricting argument is also identical. Each caller is reported on its own line. The format differs slightly depending on the profiler that produced the stats:

- With `profile`, a number is shown in parentheses after each caller to show how many times this specific call was made. For convenience, a second non-parenthesized number repeats the cumulative time spent in the function at the right.
- With `cProfile`, each caller is preceded by three numbers: the number of times this specific call was made, and the total and cumulative times spent in the current function while it was invoked by this specific caller.

`Stats.print_callees([restriction, ...])`

This method for the `Stats` class prints a list of all function that were called by the indicated function. Aside from this reversal of direction of calls (re: called vs was called by), the arguments and ordering are identical to the `print_callers()` method.

### 26.4.5 Limitations

One limitation has to do with accuracy of timing information. There is a fundamental problem with deterministic profilers involving accuracy. The most obvious restriction is that the underlying “clock” is only ticking at a rate (typically) of about .001 seconds. Hence no measurements will be more accurate than the underlying clock. If enough measurements are taken, then the “error” will tend to average out. Unfortunately, removing this first error induces a second source of error.

The second problem is that it “takes a while” from when an event is dispatched until the profiler’s call to get the time actually *gets* the state of the clock. Similarly, there is a certain lag when exiting the profiler event handler from the time that the clock’s value was obtained (and then squirreled away), until the user’s code is once again executing. As a result, functions that are called many times, or call many functions, will typically accumulate this error. The error that accumulates in this fashion is typically less than the accuracy of the clock (less than one clock tick), but it *can* accumulate and become very significant.

The problem is more important with `profile` than with the lower-overhead `cProfile`. For this reason, `profile` provides a means of calibrating itself for a given platform so that this error can be probabilistically (on the average) removed. After the profiler is calibrated, it will be more accurate (in a least square sense), but it will sometimes produce negative numbers (when call counts are exceptionally low, and the gods of probability work against you :-). ) Do *not* be alarmed by negative numbers in the profile. They should *only* appear if you have calibrated your profiler, and the results are actually better than without calibration.

### 26.4.6 Calibration

The profiler of the `profile` module subtracts a constant from each event handling time to compensate for the overhead of calling the time function, and socking away the results. By default, the constant is 0. The following procedure can be used to obtain a better constant for a given platform (see discussion in section Limitations above).

```
import profile
pr = profile.Profile()
for i in range(5):
    print pr.calibrate(10000)
```

The method executes the number of Python calls given by the argument, directly and again under the profiler, measuring the time for both. It then computes the hidden overhead per profiler event, and returns that as a float. For example, on an 800 MHz Pentium running Windows 2000, and using Python’s `time.clock()` as the timer, the magical number is about 12.5e-6.

The object of this exercise is to get a fairly consistent result. If your computer is *very* fast, or your timer function has poor resolution, you might have to pass 100000, or even 1000000, to get consistent results.

When you have a consistent answer, there are three ways you can use it: <sup>2</sup>

```
import profile
```

```
# 1. Apply computed bias to all Profile instances created hereafter.
profile.Profile.bias = your_computed_bias
```

```
# 2. Apply computed bias to a specific Profile instance.
pr = profile.Profile()
pr.bias = your_computed_bias
```

```
# 3. Specify computed bias in instance constructor.
pr = profile.Profile(bias=your_computed_bias)
```

If you have a choice, you are better off choosing a smaller constant, and then your results will “less often” show up as negative in profile statistics.

### 26.4.7 Extensions — Deriving Better Profilers

The `Profile` class of both modules, `profile` and `cProfile`, were written so that derived classes could be developed to extend the profiler. The details are not described here, as doing this successfully requires an expert understanding of how the `Profile` class works internally. Study the source code of the module carefully if you want to pursue this.

If all you want to do is change how current time is determined (for example, to force use of wall-clock time or elapsed process time), pass the timing function you want to the `Profile` class constructor:

```
pr = profile.Profile(your_time_func)
```

The resulting profiler will then call `your_time_func()`.

**profile.Profile** `your_time_func()` should return a single number, or a list of numbers whose sum is the current time (like what `os.times()` returns). If the function returns a single time number, or the list of returned numbers has length 2, then you will get an especially fast version of the dispatch routine.

Be warned that you should calibrate the profiler class for the timer function that you choose. For most machines, a timer that returns a lone integer value will provide the best results in terms of low overhead during profiling. (`os.times()` is *pretty* bad, as it returns a tuple of floating point values). If you want to substitute a better timer in the cleanest fashion, derive a class and hardwire a replacement dispatch method that best handles your timer call, along with the appropriate calibration constant.

**cProfile.Profile** `your_time_func()` should return a single number. If it returns plain integers, you can also invoke the class constructor with a second argument specifying the real duration of one unit of time. For example, if `your_integer_time_func()` returns times measured in thousands of seconds, you would construct the `Profile` instance as follows:

```
pr = profile.Profile(your_integer_time_func, 0.001)
```

As the `cProfile.Profile` class cannot be calibrated, custom timer functions should be used with care and should be as fast as possible. For the best results with a custom timer, it might be necessary to hard-code it in the C source of the internal `_lsprof` module.

---

<sup>2</sup> Prior to Python 2.2, it was necessary to edit the profiler source code to embed the bias as a literal number. You still can, but that method is no longer described, because no longer needed.

## 26.5 hotshot — High performance logging profiler

New in version 2.2. This module provides a nicer interface to the `_hotshot` C module. Hotshot is a replacement for the existing `profile` module. As it's written mostly in C, it should result in a much smaller performance impact than the existing `profile` module.

---

**Note:** The `hotshot` module focuses on minimizing the overhead while profiling, at the expense of long data post-processing times. For common usage it is recommended to use `cProfile` instead. `hotshot` is not maintained and might be removed from the standard library in the future.

---

Changed in version 2.5: The results should be more meaningful than in the past: the timing core contained a critical bug.

---

**Note:** The `hotshot` profiler does not yet work well with threads. It is useful to use an unthreaded script to run the profiler over the code you're interested in measuring if at all possible.

---

**class** `hotshot.Profile` (*logfile* [, *lineevents* [, *linetimings* ] ])

The profiler object. The argument *logfile* is the name of a log file to use for logged profile data. The argument *lineevents* specifies whether to generate events for every source line, or just on function call/return. It defaults to 0 (only log function call/return). The argument *linetimings* specifies whether to record timing information. It defaults to 1 (store timing information).

### 26.5.1 Profile Objects

Profile objects have the following methods:

`Profile.addinfo` (*key*, *value*)

Add an arbitrary labelled value to the profile output.

`Profile.close` ()

Close the logfile and terminate the profiler.

`Profile_FILENO` ()

Return the file descriptor of the profiler's log file.

`Profile.run` (*cmd*)

Profile an `exec`-compatible string in the script environment. The globals from the `__main__` module are used as both the globals and locals for the script.

`Profile.runcall` (*func*, *\*args*, *\*\*keywords*)

Profile a single call of a callable. Additional positional and keyword arguments may be passed along; the result of the call is returned, and exceptions are allowed to propagate cleanly, while ensuring that profiling is disabled on the way out.

`Profile.runctx` (*cmd*, *globals*, *locals*)

Evaluate an `exec`-compatible string in a specific environment. The string is compiled before profiling begins.

`Profile.start` ()

Start the profiler.

`Profile.stop` ()

Stop the profiler.

## 26.5.2 Using hotshot data

New in version 2.2. This module loads hotshot profiling data into the standard `pstats` Stats objects.

```
hotshot.stats.load(filename)
```

Load hotshot data from *filename*. Returns an instance of the `pstats.Stats` class.

**See Also:**

**Module `profile`** The `profile` module's Stats class

## 26.5.3 Example Usage

Note that this example runs the Python “benchmark” pystones. It can take some time to run, and will produce large output files.

```
>>> import hotshot, hotshot.stats, test.pystone
>>> prof = hotshot.Profile("stones.prof")
>>> benchtime, stones = prof.runcall(test.pystone.pystones)
>>> prof.close()
>>> stats = hotshot.stats.load("stones.prof")
>>> stats.strip_dirs()
>>> stats.sort_stats('time', 'calls')
>>> stats.print_stats(20)
      850004 function calls in 10.090 CPU seconds
```

Ordered by: internal time, call count

ncalls	tottime	percall	cumtime	percall	filename:lineno(function)
1	3.295	3.295	10.090	10.090	pystone.py:79(Proc0)
150000	1.315	0.000	1.315	0.000	pystone.py:203(Proc7)
50000	1.313	0.000	1.463	0.000	pystone.py:229(Func2)
.					
.					
.					

## 26.6 `timeit` — Measure execution time of small code snippets

New in version 2.3. **Source code:** [Lib/timeit.py](#)

---

This module provides a simple way to time small bits of Python code. It has both command line as well as callable interfaces. It avoids a number of common traps for measuring execution times. See also Tim Peters' introduction to the “Algorithms” chapter in the Python Cookbook, published by O'Reilly.

The module defines the following public class:

```
class timeit.Timer(stmt='pass', setup='pass', timer=<timer function>)
```

Class for timing execution speed of small code snippets.

The constructor takes a statement to be timed, an additional statement used for setup, and a timer function. Both statements default to 'pass'; the timer function is platform-dependent (see the module doc string). *stmt* and *setup* may also contain multiple statements separated by ; or newlines, as long as they don't contain multi-line string literals.

To measure the execution time of the first statement, use the `Timer.timeit()` method. The `repeat()` method is a convenience to call `timeit()` multiple times and return a list of results. Changed in version 2.6: The `stmt` and `setup` parameters can now also take objects that are callable without arguments. This will embed calls to them in a timer function that will then be executed by `timeit()`. Note that the timing overhead is a little larger in this case because of the extra function calls.

`Timer.print_exc` (*file=None*)

Helper to print a traceback from the timed code.

Typical use:

```
t = Timer(...)          # outside the try/except
try:
    t.timeit(...)       # or t.repeat(...)
except:
    t.print_exc()
```

The advantage over the standard traceback is that source lines in the compiled template will be displayed. The optional `file` argument directs where the traceback is sent; it defaults to `sys.stderr`.

`Timer.repeat` (*repeat=3, number=1000000*)

Call `timeit()` a few times.

This is a convenience function that calls the `timeit()` repeatedly, returning a list of results. The first argument specifies how many times to call `timeit()`. The second argument specifies the `number` argument for `timeit()`.

---

**Note:** It's tempting to calculate mean and standard deviation from the result vector and report these. However, this is not very useful. In a typical case, the lowest value gives a lower bound for how fast your machine can run the given code snippet; higher values in the result vector are typically not caused by variability in Python's speed, but by other processes interfering with your timing accuracy. So the `min()` of the result is probably the only number you should be interested in. After that, you should look at the entire vector and apply common sense rather than statistics.

---

`Timer.timeit` (*number=1000000*)

Time `number` executions of the main statement. This executes the setup statement once, and then returns the time it takes to execute the main statement a number of times, measured in seconds as a float. The argument is the number of times through the loop, defaulting to one million. The main statement, the setup statement and the timer function to be used are passed to the constructor.

---

**Note:** By default, `timeit()` temporarily turns off *garbage collection* during the timing. The advantage of this approach is that it makes independent timings more comparable. This disadvantage is that GC may be an important component of the performance of the function being measured. If so, GC can be re-enabled as the first statement in the `setup` string. For example:

```
timeit.Timer('for i in xrange(10): oct(i)', 'gc.enable()').timeit()
```

---

The module also defines three convenience functions:

`timeit.default_timer` ()

Define a default timer, in a platform specific manner. On Windows, `time.clock()` has microsecond granularity but `time.time()`'s granularity is 1/60th of a second; on Unix, `time.clock()` has 1/100th of a second granularity and `time.time()` is much more precise. On either platform, `default_timer()` measures wall clock time, not the CPU time. This means that other processes running on the same computer may interfere with the timing.

`timeit.repeat(stmt, setup='pass', timer=default_timer, repeat=3, number=1000000)`

Create a `Timer` instance with the given statement, setup code and timer function and run its `repeat()` method with the given repeat count and `number` executions. New in version 2.6.

`timeit.timeit(stmt, setup='pass', timer=default_timer, number=1000000)`

Create a `Timer` instance with the given statement, setup code and timer function and run its `timeit()` method with `number` executions. New in version 2.6.

### 26.6.1 Command Line Interface

When called as a program from the command line, the following form is used:

```
python -m timeit [-n N] [-r N] [-s S] [-t] [-c] [-h] [statement ...]
```

Where the following options are understood:

- n N, -number=N**  
how many times to execute 'statement'
- r N, -repeat=N**  
how many times to repeat the timer (default 3)
- s S, -setup=S**  
statement to be executed once initially (default `pass`)
- t, -time**  
use `time.time()` (default on all platforms but Windows)
- c, -clock**  
use `time.clock()` (default on Windows)
- v, -verbose**  
print raw timing results; repeat for more digits precision
- h, -help**  
print a short usage message and exit

A multi-line statement may be given by specifying each line as a separate statement argument; indented lines are possible by enclosing an argument in quotes and using leading spaces. Multiple `-s` options are treated similarly.

If `-n` is not given, a suitable number of loops is calculated by trying successive powers of 10 until the total time is at least 0.2 seconds.

`default_timer()` measurements can be affected by other programs running on the same machine, so the best thing to do when accurate timing is necessary is to repeat the timing a few times and use the best time. The `-r` option is good for this; the default of 3 repetitions is probably enough in most cases. On Unix, you can use `time.clock()` to measure CPU time.

---

**Note:** There is a certain baseline overhead associated with executing a `pass` statement. The code here doesn't try to hide it, but you should be aware of it. The baseline overhead can be measured by invoking the program without arguments.

---

The baseline overhead differs between Python versions! Also, to fairly compare older Python versions to Python 2.3, you may want to use Python's `-O` option for the older versions to avoid timing `SET_LINENO` instructions.

## 26.6.2 Examples

Here are two example sessions (one using the command line, one using the module interface) that compare the cost of using `hasattr()` vs. `try/except` to test for missing and present object attributes.

```
$ python -m timeit 'try: ' str.__nonzero__ 'except AttributeError: ' pass'
100000 loops, best of 3: 15.7 usec per loop
$ python -m timeit 'if hasattr(str, "__nonzero__"): pass'
100000 loops, best of 3: 4.26 usec per loop
$ python -m timeit 'try: ' int.__nonzero__ 'except AttributeError: ' pass'
1000000 loops, best of 3: 1.43 usec per loop
$ python -m timeit 'if hasattr(int, "__nonzero__"): pass'
100000 loops, best of 3: 2.23 usec per loop
```

```
>>> import timeit
>>> s = """\
... try:
...     str.__nonzero__
... except AttributeError:
...     pass
... """
>>> t = timeit.Timer(stmt=s)
>>> print "%.2f usec/pass" % (1000000 * t.timeit(number=100000)/100000)
17.09 usec/pass
>>> s = """\
... if hasattr(str, '__nonzero__'): pass
... """
>>> t = timeit.Timer(stmt=s)
>>> print "%.2f usec/pass" % (1000000 * t.timeit(number=100000)/100000)
4.85 usec/pass
>>> s = """\
... try:
...     int.__nonzero__
... except AttributeError:
...     pass
... """
>>> t = timeit.Timer(stmt=s)
>>> print "%.2f usec/pass" % (1000000 * t.timeit(number=100000)/100000)
1.97 usec/pass
>>> s = """\
... if hasattr(int, '__nonzero__'): pass
... """
>>> t = timeit.Timer(stmt=s)
>>> print "%.2f usec/pass" % (1000000 * t.timeit(number=100000)/100000)
3.15 usec/pass
```

To give the `timeit` module access to functions you define, you can pass a `setup` parameter which contains an import statement:

```
def test():
    """Stupid test function"""
    L = []
    for i in range(100):
        L.append(i)

if __name__ == '__main__':
```

```
from timeit import Timer
t = Timer("test()", "from __main__ import test")
print t.timeit()
```

## 26.7 `trace` — Trace or track Python statement execution

Source code: [Lib/trace.py](#)

---

The `trace` module allows you to trace program execution, generate annotated statement coverage listings, print caller/callee relationships and list functions executed during a program run. It can be used in another program or from the command line.

### 26.7.1 Command-Line Usage

The `trace` module can be invoked from the command line. It can be as simple as

```
python -m trace --count -C . somefile.py ...
```

The above will execute `somefile.py` and generate annotated listings of all Python modules imported during the execution into the current directory.

**-help**

Display usage and exit.

**-version**

Display the version of the module and exit.

#### Main options

At least one of the following options must be specified when invoking `trace`. The `--listfuncs` option is mutually exclusive with the `--trace` and `--counts` options. When `--listfuncs` is provided, neither `--counts` nor `--trace` are accepted, and vice versa.

**-c, -count**

Produce a set of annotated listing files upon program completion that shows how many times each statement was executed. See also `--coverdir`, `--file` and `--no-report` below.

**-t, -trace**

Display lines as they are executed.

**-l, -listfuncs**

Display the functions executed by running the program.

**-r, -report**

Produce an annotated list from an earlier program run that used the `--count` and `--file` option. This does not execute any code.

**-T, -trackcalls**

Display the calling relationships exposed by running the program.

## Modifiers

- f, -file=<file>**  
Name of a file to accumulate counts over several tracing runs. Should be used with the `--count` option.
- C, -coverdir=<dir>**  
Directory where the report files go. The coverage report for `package.module` is written to file `dir/package/module.cover`.
- m, -missing**  
When generating annotated listings, mark lines which were not executed with `>>>>>>`.
- s, -summary**  
When using `--count` or `--report`, write a brief summary to stdout for each file processed.
- R, -no-report**  
Do not generate annotated listings. This is useful if you intend to make several runs with `--count`, and then produce a single set of annotated listings at the end.
- g, -timing**  
Prefix each line with the time since the program started. Only used while tracing.

## Filters

These options may be repeated multiple times.

- ignore-module=<mod>**  
Ignore each of the given module names and its submodules (if it is a package). The argument can be a list of names separated by a comma.
- ignore-dir=<dir>**  
Ignore all modules and packages in the named directory and subdirectories. The argument can be a list of directories separated by `os.pathsep`.

## 26.7.2 Programmatic Interface

```
class trace.Trace ([count=1[, trace=1[, countfuncs=0[, countcallers=0[, ignoremods=()[, ig-
                    noredirs=()[, infile=None[, outfile=None[, timing=False ]]]]]]]])
```

Create an object to trace execution of a single statement or expression. All parameters are optional. `count` enables counting of line numbers. `trace` enables line execution tracing. `countfuncs` enables listing of the functions called during the run. `countcallers` enables call relationship tracking. `ignoremods` is a list of modules or packages to ignore. `ignoredirs` is a list of directories whose modules or packages should be ignored. `infile` is the name of the file from which to read stored count information. `outfile` is the name of the file in which to write updated count information. `timing` enables a timestamp relative to when tracing was started to be displayed.

**run** (*cmd*)

Execute the command and gather statistics from the execution with the current tracing parameters. *cmd* must be a string or code object, suitable for passing into `exec()`.

**runctx** (*cmd*, *globals=None*, *locals=None*)

Execute the command and gather statistics from the execution with the current tracing parameters, in the defined global and local environments. If not defined, *globals* and *locals* default to empty dictionaries.

**runfunc** (*func*, *\*args*, *\*\*kwds*)

Call *func* with the given arguments under control of the `Trace` object with the current tracing parameters.

**results()**

Return a `CoverageResults` object that contains the cumulative results of all previous calls to `run`, `runctx` and `runfunc` for the given `Trace` instance. Does not reset the accumulated trace results.

**class** `trace.CoverageResults`

A container for coverage results, created by `Trace.results()`. Should not be created directly by the user.

**update**(*other*)

Merge in data from another `CoverageResults` object.

**write\_results**(`[show_missing=True[, summary=False[, coverdir=None]]]`)

Write coverage results. Set `show_missing` to show lines that had no hits. Set `summary` to include in the output the coverage summary per module. `coverdir` specifies the directory into which the coverage result files will be output. If `None`, the results for each source file are placed in its directory.

A simple example demonstrating the use of the programmatic interface:

```
import sys
import trace

# create a Trace object, telling it what to ignore, and whether to
# do tracing or line-counting or both.
tracer = trace.Trace(
    ignoredirs=[sys.prefix, sys.exec_prefix],
    trace=0,
    count=1)

# run the new command using the given tracer
tracer.run('main()')

# make a report, placing output in /tmp
r = tracer.results()
r.write_results(show_missing=True, coverdir="/tmp")
```

# PYTHON RUNTIME SERVICES

The modules described in this chapter provide a wide range of services related to the Python interpreter and its interaction with its environment. Here's an overview:

## 27.1 `sys` — System-specific parameters and functions

This module provides access to some variables used or maintained by the interpreter and to functions that interact strongly with the interpreter. It is always available.

### `sys.argv`

The list of command line arguments passed to a Python script. `argv[0]` is the script name (it is operating system dependent whether this is a full pathname or not). If the command was executed using the `-c` command line option to the interpreter, `argv[0]` is set to the string `'-c'`. If no script name was passed to the Python interpreter, `argv[0]` is the empty string.

To loop over the standard input, or the list of files given on the command line, see the `fileinput` module.

### `sys.byteorder`

An indicator of the native byte order. This will have the value `'big'` on big-endian (most-significant byte first) platforms, and `'little'` on little-endian (least-significant byte first) platforms. New in version 2.0.

### `sys.builtin_module_names`

A tuple of strings giving the names of all modules that are compiled into this Python interpreter. (This information is not available in any other way — `modules.keys()` only lists the imported modules.)

### `sys.call_tracing(func, args)`

Call `func(*args)`, while tracing is enabled. The tracing state is saved, and restored afterwards. This is intended to be called from a debugger from a checkpoint, to recursively debug some other code.

### `sys.copyright`

A string containing the copyright pertaining to the Python interpreter.

### `sys._clear_type_cache()`

Clear the internal type cache. The type cache is used to speed up attribute and method lookups. Use the function *only* to drop unnecessary references during reference leak debugging.

This function should be used for internal and specialized purposes only. New in version 2.6.

### `sys._current_frames()`

Return a dictionary mapping each thread's identifier to the topmost stack frame currently active in that thread at the time the function is called. Note that functions in the `traceback` module can build the call stack given such a frame.

This is most useful for debugging deadlock: this function does not require the deadlocked threads' cooperation, and such threads' call stacks are frozen for as long as they remain deadlocked. The frame returned for a non-deadlocked thread may bear no relationship to that thread's current activity by the time calling code examines the frame.

This function should be used for internal and specialized purposes only. New in version 2.5.

`sys.dllhandle`

Integer specifying the handle of the Python DLL. Availability: Windows.

`sys.displayhook` (*value*)

If *value* is not None, this function prints it to `sys.stdout`, and saves it in `__builtin__.__`.

`sys.displayhook` is called on the result of evaluating an *expression* entered in an interactive Python session. The display of these values can be customized by assigning another one-argument function to `sys.displayhook`.

`sys.dont_write_bytecode`

If this is true, Python won't try to write `.pyc` or `.pyo` files on the import of source modules. This value is initially set to True or False depending on the `-B` command line option and the

`PYTHONDONTWRITEBYTECODE` environment variable, but you can set it yourself to control bytecode file generation. New in version 2.6.

`sys.excepthook` (*type, value, traceback*)

This function prints out a given traceback and exception to `sys.stderr`.

When an exception is raised and uncaught, the interpreter calls `sys.excepthook` with three arguments, the exception class, exception instance, and a traceback object. In an interactive session this happens just before control is returned to the prompt; in a Python program this happens just before the program exits. The handling of such top-level exceptions can be customized by assigning another three-argument function to `sys.excepthook`.

`sys.__displayhook__`

`sys.__excepthook__`

These objects contain the original values of `displayhook` and `excepthook` at the start of the program. They are saved so that `displayhook` and `excepthook` can be restored in case they happen to get replaced with broken objects.

`sys.exc_info()`

This function returns a tuple of three values that give information about the exception that is currently being handled. The information returned is specific both to the current thread and to the current stack frame. If the current stack frame is not handling an exception, the information is taken from the calling stack frame, or its caller, and so on until a stack frame is found that is handling an exception. Here, "handling an exception" is defined as "executing or having executed an except clause." For any stack frame, only information about the most recently handled exception is accessible.

If no exception is being handled anywhere on the stack, a tuple containing three None values is returned. Otherwise, the values returned are (*type, value, traceback*). Their meaning is: *type* gets the exception type of the exception being handled (a class object); *value* gets the exception parameter (its *associated value* or the second argument to `raise`, which is always a class instance if the exception type is a class object); *traceback* gets a traceback object (see the Reference Manual) which encapsulates the call stack at the point where the exception originally occurred.

If `exc_clear()` is called, this function will return three None values until either another exception is raised in the current thread or the execution stack returns to a frame where another exception is being handled.

**Warning:** Assigning the *traceback* return value to a local variable in a function that is handling an exception will cause a circular reference. This will prevent anything referenced by a local variable in the same function or by the traceback from being garbage collected. Since most functions don't need access to the traceback, the best solution is to use something like `exc_type, value = sys.exc_info()[:2]` to extract only the exception type and value. If you do need the traceback, make sure to delete it after use (best done with a `try ... finally` statement) or to call `exc_info()` in a function that does not itself handle an exception.

**Note:** Beginning with Python 2.2, such cycles are automatically reclaimed when garbage collection is enabled and they become unreachable, but it remains more efficient to avoid creating cycles.

`sys.exc_clear()`

This function clears all information relating to the current or last exception that occurred in the current thread. After calling this function, `exc_info()` will return three `None` values until another exception is raised in the current thread or the execution stack returns to a frame where another exception is being handled.

This function is only needed in only a few obscure situations. These include logging and error handling systems that report information on the last or current exception. This function can also be used to try to free resources and trigger object finalization, though no guarantee is made as to what objects will be freed, if any. New in version 2.3.

`sys.exc_type`

`sys.exc_value`

`sys.exc_traceback`

Deprecated since version 1.5: Use `exc_info()` instead. Since they are global variables, they are not specific to the current thread, so their use is not safe in a multi-threaded program. When no exception is being handled, `exc_type` is set to `None` and the other two are undefined.

`sys.exec_prefix`

A string giving the site-specific directory prefix where the platform-dependent Python files are installed; by default, this is also `'/usr/local'`. This can be set at build time with the `--exec-prefix` argument to the `configure` script. Specifically, all configuration files (e.g. the `pyconfig.h` header file) are installed in the directory `exec_prefix/lib/pythonX.Y/config`, and shared library modules are installed in `exec_prefix/lib/pythonX.Y/lib-dynload`, where `X.Y` is the version number of Python, for example 2.7.

`sys.executable`

A string giving the absolute path of the executable binary for the Python interpreter, on systems where this makes sense. If Python is unable to retrieve the real path to its executable, `sys.executable` will be an empty string or `None`.

`sys.exit([arg])`

Exit from Python. This is implemented by raising the `SystemExit` exception, so cleanup actions specified by finally clauses of `try` statements are honored, and it is possible to intercept the exit attempt at an outer level.

The optional argument `arg` can be an integer giving the exit status (defaulting to zero), or another type of object. If it is an integer, zero is considered “successful termination” and any nonzero value is considered “abnormal termination” by shells and the like. Most systems require it to be in the range 0-127, and produce undefined results otherwise. Some systems have a convention for assigning specific meanings to specific exit codes, but these are generally underdeveloped; Unix programs generally use 2 for command line syntax errors and 1 for all other kind of errors. If another type of object is passed, `None` is equivalent to passing zero, and any other object is printed to `stderr` and results in an exit code of 1. In particular, `sys.exit("some error message")` is a quick way to exit a program when an error occurs.

Since `exit()` ultimately “only” raises an exception, it will only exit the process when called from the main thread, and the exception is not intercepted.

**sys.exitfunc**

This value is not actually defined by the module, but can be set by the user (or by a program) to specify a clean-up action at program exit. When set, it should be a parameterless function. This function will be called when the interpreter exits. Only one function may be installed in this way; to allow multiple functions which will be called at termination, use the `atexit` module.

---

**Note:** The exit function is not called when the program is killed by a signal, when a Python fatal internal error is detected, or when `os._exit()` is called.

---

Deprecated since version 2.4: Use `atexit` instead.

**sys.flags**

The struct sequence *flags* exposes the status of command line flags. The attributes are read only.

attribute	flag
<code>debug</code>	<code>-d</code>
<code>py3k_warning</code>	<code>-3</code>
<code>division_warning</code>	<code>-Q</code>
<code>division_new</code>	<code>-Qnew</code>
<code>inspect</code>	<code>-i</code>
<code>interactive</code>	<code>-i</code>
<code>optimize</code>	<code>-O</code> or <code>-OO</code>
<code>dont_write_bytecode</code>	<code>-B</code>
<code>no_user_site</code>	<code>-s</code>
<code>no_site</code>	<code>-S</code>
<code>ignore_environment</code>	<code>-E</code>
<code>tabcheck</code>	<code>-t</code> or <code>-tt</code>
<code>verbose</code>	<code>-v</code>
<code>unicode</code>	<code>-U</code>
<code>bytes_warning</code>	<code>-b</code>
<code>hash_randomization</code>	<code>-R</code>

New in version 2.6. New in version 2.7.3: The `hash_randomization` attribute.

**sys.float\_info**

A structseq holding information about the float type. It contains low level information about the precision and internal representation. The values correspond to the various floating-point constants defined in the standard header file `float.h` for the 'C' programming language; see section 5.2.4.2.2 of the 1999 ISO/IEC C standard [C99], 'Characteristics of floating types', for details.

at-tribute	float.h macro	explanation
epsilon	DBL_EPSILON	Difference between 1 and the least value greater than 1 that is representable as a float
dig	DBL_DIG	maximum number of decimal digits that can be faithfully represented in a float; see below
mant_dig	DBL_MANT_DIG	precision: the number of base-radix digits in the significand of a float
max	DBL_MAX	maximum representable finite float
max_exp	DBL_MAX_EXP	maximum integer e such that $\text{radix}^{**}(e-1)$ is a representable finite float
max_10	DBL_MAX_10_EXP	maximum integer e such that $10^{**}e$ is in the range of representable finite floats
min	DBL_MIN	minimum positive normalized float
min_exp	DBL_MIN_EXP	minimum integer e such that $\text{radix}^{**}(e-1)$ is a normalized float
min_10	DBL_MIN_10_EXP	minimum integer e such that $10^{**}e$ is a normalized float
radix	FLT_RADIX	radix of exponent representation
rounds	FLT_ROUNDS	integer constant representing the rounding mode used for arithmetic operations. This reflects the value of the system FLT_ROUNDS macro at interpreter startup time. See section 5.2.4.2.2 of the C99 standard for an explanation of the possible values and their meanings.

The attribute `sys.float_info.dig` needs further explanation. If `s` is any string representing a decimal number with at most `sys.float_info.dig` significant digits, then converting `s` to a float and back again will recover a string representing the same decimal value:

```
>>> import sys
>>> sys.float_info.dig
15
>>> s = '3.14159265358979'      # decimal string with 15 significant digits
>>> format(float(s), '.15g')   # convert to float and back -> same value
'3.14159265358979'
```

But for strings with more than `sys.float_info.dig` significant digits, this isn't always true:

```
>>> s = '9876543211234567'    # 16 significant digits is too many!
>>> format(float(s), '.16g')   # conversion changes value
'9876543211234568'
```

New in version 2.6.

#### `sys.float_repr_style`

A string indicating how the `repr()` function behaves for floats. If the string has value `'short'` then for a finite float `x`, `repr(x)` aims to produce a short string with the property that `float(repr(x)) == x`. This is the usual behaviour in Python 2.7 and later. Otherwise, `float_repr_style` has value `'legacy'` and `repr(x)` behaves in the same way as it did in versions of Python prior to 2.7. New in version 2.7.

#### `sys.getcheckinterval()`

Return the interpreter's "check interval"; see `setcheckinterval()`. New in version 2.3.

#### `sys.getdefaultencoding()`

Return the name of the current default string encoding used by the Unicode implementation. New in version 2.0.

#### `sys.getdlopenflags()`

Return the current value of the flags that are used for `dlopen()` calls. The flag constants are defined in the `dl` and `DLFCN` modules. Availability: Unix. New in version 2.2.

#### `sys.getfilesystemencoding()`

Return the name of the encoding used to convert Unicode filenames into system file names, or `None` if the

system default encoding is used. The result value depends on the operating system:

- On Mac OS X, the encoding is `'utf-8'`.
- On Unix, the encoding is the user's preference according to the result of `nl_langinfo(CODESET)`, or `None` if the `nl_langinfo(CODESET)` failed.
- On Windows NT+, file names are Unicode natively, so no conversion is performed. `getfilesystemencoding()` still returns `'mbcs'`, as this is the encoding that applications should use when they explicitly want to convert Unicode strings to byte strings that are equivalent when used as file names.
- On Windows 9x, the encoding is `'mbcs'`.

New in version 2.3.

`sys.getrefcount(object)`

Return the reference count of the *object*. The count returned is generally one higher than you might expect, because it includes the (temporary) reference as an argument to `getrefcount()`.

`sys.getrecursionlimit()`

Return the current value of the recursion limit, the maximum depth of the Python interpreter stack. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python. It can be set by `setrecursionlimit()`.

`sys.getsizeof(object[, default])`

Return the size of an object in bytes. The object can be any type of object. All built-in objects will return correct results, but this does not have to hold true for third-party extensions as it is implementation specific.

If given, *default* will be returned if the object does not provide means to retrieve the size. Otherwise a `TypeError` will be raised.

`getsizeof()` calls the object's `__sizeof__` method and adds an additional garbage collector overhead if the object is managed by the garbage collector. New in version 2.6.

`sys._getframe([depth])`

Return a frame object from the call stack. If optional integer *depth* is given, return the frame object that many calls below the top of the stack. If that is deeper than the call stack, `ValueError` is raised. The default for *depth* is zero, returning the frame at the top of the call stack.

**CPython implementation detail:** This function should be used for internal and specialized purposes only. It is not guaranteed to exist in all implementations of Python.

`sys.getprofile()`

Get the profiler function as set by `setprofile()`. New in version 2.6.

`sys.gettrace()`

Get the trace function as set by `settrace()`.

**CPython implementation detail:** The `gettrace()` function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be available in all Python implementations. New in version 2.6.

`sys.getwindowsversion()`

Return a named tuple describing the Windows version currently running. The named elements are *major*, *minor*, *build*, *platform*, *service\_pack*, *service\_pack\_minor*, *service\_pack\_major*, *suite\_mask*, and *product\_type*. *service\_pack* contains a string while all other values are integers. The components can also be accessed by name, so `sys.getwindowsversion()[0]` is equivalent to `sys.getwindowsversion().major`. For compatibility with prior versions, only the first 5 elements are retrievable by indexing.

*platform* may be one of the following values:

Constant	Platform
0 (VER_PLATFORM_WIN32s)	Win32s on Windows 3.1
1 (VER_PLATFORM_WIN32_WINDOWS)	Windows 95/98/ME
2 (VER_PLATFORM_WIN32_NT)	Windows NT/2000/XP/x64
3 (VER_PLATFORM_WIN32_CE)	Windows CE

`product_type` may be one of the following values:

Constant	Meaning
1 (VER_NT_WORKSTATION)	The system is a workstation.
2 (VER_NT_DOMAIN_CONTROLLER)	The system is a domain controller.
3 (VER_NT_SERVER)	The system is a server, but not a domain controller.

This function wraps the Win32 `GetVersionEx()` function; see the Microsoft documentation on `OSVERSIONINFOEX()` for more information about these fields.

Availability: Windows. New in version 2.3.Changed in version 2.7: Changed to a named tuple and added `service_pack_minor`, `service_pack_major`, `suite_mask`, and `product_type`.

### `sys.hexversion`

The version number encoded as a single integer. This is guaranteed to increase with each version, including proper support for non-production releases. For example, to test that the Python interpreter is at least version 1.5.2, use:

```
if sys.hexversion >= 0x010502F0:
    # use some advanced feature
    ...
else:
    # use an alternative implementation or warn the user
    ...
```

This is called `hexversion` since it only really looks meaningful when viewed as the result of passing it to the built-in `hex()` function. The `version_info` value may be used for a more human-friendly encoding of the same information.

The `hexversion` is a 32-bit number with the following layout:

Bits (big endian order)	Meaning
1-8	PY_MAJOR_VERSION (the 2 in 2.1.0a3)
9-16	PY_MINOR_VERSION (the 1 in 2.1.0a3)
17-24	PY_MICRO_VERSION (the 0 in 2.1.0a3)
25-28	PY_RELEASE_LEVEL (0xA for alpha, 0xB for beta, 0xC for release candidate and 0xF for final)
29-32	PY_RELEASE_SERIAL (the 3 in 2.1.0a3, zero for final releases)

Thus 2.1.0a3 is `hexversion` 0x020100a3. New in version 1.5.2.

### `sys.long_info`

A struct sequence that holds information about Python's internal representation of integers. The attributes are read only.

Attribute	Explanation
<code>bits_per_digit</code>	number of bits held in each digit. Python integers are stored internally in base $2^{**long\_info.bits\_per\_digit}$
<code>sizeof_digit</code>	size in bytes of the C type used to represent a digit

New in version 2.7.

### `sys.last_type`

`sys.last_value`

`sys.last_traceback`

These three variables are not always defined; they are set when an exception is not handled and the interpreter prints an error message and a stack traceback. Their intended use is to allow an interactive user to import a debugger module and engage in post-mortem debugging without having to re-execute the command that caused the error. (Typical use is `import pdb; pdb.pm()` to enter the post-mortem debugger; see chapter *pdb — The Python Debugger* for more information.)

The meaning of the variables is the same as that of the return values from `exc_info()` above. (Since there is only one interactive thread, thread-safety is not a concern for these variables, unlike for `exc_type` etc.)

`sys.maxint`

The largest positive integer supported by Python's regular integer type. This is at least  $2^{31}-1$ . The largest negative integer is `-maxint-1` — the asymmetry results from the use of 2's complement binary arithmetic.

`sys.maxsize`

The largest positive integer supported by the platform's `Py_ssize_t` type, and thus the maximum size lists, strings, dicts, and many other containers can have.

`sys.maxunicode`

An integer giving the largest supported code point for a Unicode character. The value of this depends on the configuration option that specifies whether Unicode characters are stored as UCS-2 or UCS-4.

`sys.meta_path`

A list of *finder* objects that have their `find_module()` methods called to see if one of the objects can find the module to be imported. The `find_module()` method is called at least with the absolute name of the module being imported. If the module to be imported is contained in package then the parent package's `__path__` attribute is passed in as a second argument. The method returns `None` if the module cannot be found, else returns a *loader*.

`sys.meta_path` is searched before any implicit default finders or `sys.path`.

See [PEP 302](#) for the original specification.

`sys.modules`

This is a dictionary that maps module names to modules which have already been loaded. This can be manipulated to force reloading of modules and other tricks. Note that removing a module from this dictionary is *not* the same as calling `reload()` on the corresponding module object.

`sys.path`

A list of strings that specifies the search path for modules. Initialized from the environment variable `PYTHONPATH`, plus an installation-dependent default.

As initialized upon program startup, the first item of this list, `path[0]`, is the directory containing the script that was used to invoke the Python interpreter. If the script directory is not available (e.g. if the interpreter is invoked interactively or if the script is read from standard input), `path[0]` is the empty string, which directs Python to search modules in the current directory first. Notice that the script directory is inserted *before* the entries inserted as a result of `PYTHONPATH`.

A program is free to modify this list for its own purposes. Changed in version 2.3: Unicode strings are no longer ignored.

**See Also:**

Module `site` This describes how to use `.pth` files to extend `sys.path`.

`sys.path_hooks`

A list of callables that take a path argument to try to create a *finder* for the path. If a finder can be created, it is to be returned by the callable, else raise `ImportError`.

Originally specified in [PEP 302](#).

**sys.path\_importer\_cache**

A dictionary acting as a cache for *finder* objects. The keys are paths that have been passed to `sys.path_hooks` and the values are the finders that are found. If a path is a valid file system path but no explicit finder is found on `sys.path_hooks` then `None` is stored to represent the implicit default finder should be used. If the path is not an existing path then `imp.NullImporter` is set.

Originally specified in [PEP 302](#).

**sys.platform**

This string contains a platform identifier that can be used to append platform-specific components to `sys.path`, for instance.

For most Unix systems, this is the lowercased OS name as returned by `uname -s` with the first part of the version as returned by `uname -r` appended, e.g. `'sunos5'`, *at the time when Python was built*. Unless you want to test for a specific system version, it is therefore recommended to use the following idiom:

```
if sys.platform.startswith('freebsd'):
    # FreeBSD-specific code here...
elif sys.platform.startswith('linux'):
    # Linux-specific code here...
```

Changed in version 2.7.3: Since lots of code check for `sys.platform == 'linux2'`, and there is no essential change between Linux 2.x and 3.x, `sys.platform` is always set to `'linux2'`, even on Linux 3.x. In Python 3.3 and later, the value will always be set to `'linux'`, so it is recommended to always use the `startswith` idiom presented above. For other systems, the values are:

System	platform value
Linux (2.x and 3.x)	'linux2'
Windows	'win32'
Windows/Cygwin	'cygwin'
Mac OS X	'darwin'
OS/2	'os2'
OS/2 EMX	'os2emx'
RiscOS	'riscos'
AtheOS	'atheos'

**See Also:**

`os.name` has a coarser granularity. `os.uname()` gives system-dependent version information.

The `platform` module provides detailed checks for the system's identity.

**sys.prefix**

A string giving the site-specific directory prefix where the platform independent Python files are installed; by default, this is the string `'/usr/local'`. This can be set at build time with the `--prefix` argument to the `configure` script. The main collection of Python library modules is installed in the directory `prefix/lib/pythonX.Y` while the platform independent header files (all except `pyconfig.h`) are stored in `prefix/include/pythonX.Y`, where `X.Y` is the version number of Python, for example `2.7`.

**sys.ps1****sys.ps2**

Strings specifying the primary and secondary prompt of the interpreter. These are only defined if the interpreter is in interactive mode. Their initial values in this case are `'>>> '` and `'... '`. If a non-string object is assigned to either variable, its `str()` is re-evaluated each time the interpreter prepares to read a new interactive command; this can be used to implement a dynamic prompt.

**sys.py3kwarning**

Bool containing the status of the Python 3 warning flag. It's `True` when Python is started with the `-3` option.

(This should be considered read-only; setting it to a different value doesn't have an effect on Python 3 warnings.)  
New in version 2.6.

`sys.setcheckinterval(interval)`

Set the interpreter's "check interval". This integer value determines how often the interpreter checks for periodic things such as thread switches and signal handlers. The default is 100, meaning the check is performed every 100 Python virtual instructions. Setting it to a larger value may increase performance for programs using threads. Setting it to a value  $\leq 0$  checks every virtual instruction, maximizing responsiveness as well as overhead.

`sys.setdefaultencoding(name)`

Set the current default string encoding used by the Unicode implementation. If *name* does not match any available encoding, `LookupError` is raised. This function is only intended to be used by the `site` module implementation and, where needed, by `sitecustomize`. Once used by the `site` module, it is removed from the `sys` module's namespace. New in version 2.0.

`sys.setdlopenflags(n)`

Set the flags used by the interpreter for `dlopen()` calls, such as when the interpreter loads extension modules. Among other things, this will enable a lazy resolving of symbols when importing a module, if called as `sys.setdlopenflags(0)`. To share symbols across extension modules, call as `sys.setdlopenflags(dl.RTLD_NOW | dl.RTLD_GLOBAL)`. Symbolic names for the flag modules can be either found in the `dl` module, or in the `DLFCN` module. If `DLFCN` is not available, it can be generated from `/usr/include/dlfcn.h` using the `h2py` script. Availability: Unix. New in version 2.2.

`sys.setprofile(profilefunc)`

Set the system's profile function, which allows you to implement a Python source code profiler in Python. See chapter *The Python Profilers* for more information on the Python profiler. The system's profile function is called similarly to the system's trace function (see `settrace()`), but it isn't called for each executed line of code (only on call and return, but the return event is reported even when an exception has been set). The function is thread-specific, but there is no way for the profiler to know about context switches between threads, so it does not make sense to use this in the presence of multiple threads. Also, its return value is not used, so it can simply return `None`.

`sys.setrecursionlimit(limit)`

Set the maximum depth of the Python interpreter stack to *limit*. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python.

The highest possible limit is platform-dependent. A user may need to set the limit higher when she has a program that requires deep recursion and a platform that supports a higher limit. This should be done with care, because a too-high limit can lead to a crash.

`sys.settrace(tracefunc)`

Set the system's trace function, which allows you to implement a Python source code debugger in Python. The function is thread-specific; for a debugger to support multiple threads, it must be registered using `settrace()` for each thread being debugged.

Trace functions should have three arguments: *frame*, *event*, and *arg*. *frame* is the current stack frame. *event* is a string: 'call', 'line', 'return', 'exception', 'c\_call', 'c\_return', or 'c\_exception'. *arg* depends on the event type.

The trace function is invoked (with *event* set to 'call') whenever a new local scope is entered; it should return a reference to a local trace function to be used that scope, or `None` if the scope shouldn't be traced.

The local trace function should return a reference to itself (or to another function for further tracing in that scope), or `None` to turn off tracing in that scope.

The events have the following meaning:

'call' A function is called (or some other code block entered). The global trace function is called; *arg* is `None`; the return value specifies the local trace function.

'**line**' The interpreter is about to execute a new line of code or re-execute the condition of a loop. The local trace function is called; *arg* is `None`; the return value specifies the new local trace function. See `Objects/lnotab_notes.txt` for a detailed explanation of how this works.

'**return**' A function (or other code block) is about to return. The local trace function is called; *arg* is the value that will be returned, or `None` if the event is caused by an exception being raised. The trace function's return value is ignored.

'**exception**' An exception has occurred. The local trace function is called; *arg* is a tuple (`exception`, `value`, `traceback`); the return value specifies the new local trace function.

'**c\_call**' A C function is about to be called. This may be an extension function or a built-in. *arg* is the C function object.

'**c\_return**' A C function has returned. *arg* is the C function object.

'**c\_exception**' A C function has raised an exception. *arg* is the C function object.

Note that as an exception is propagated down the chain of callers, an 'exception' event is generated at each level.

For more information on code and frame objects, refer to *types*.

**CPython implementation detail:** The `settrace()` function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be available in all Python implementations.

`sys.settsdump(on_flag)`

Activate dumping of VM measurements using the Pentium timestamp counter, if *on\_flag* is true. Deactivate these dumps if *on\_flag* is off. The function is available only if Python was compiled with `--with-tsc`. To understand the output of this dump, read `Python/ceval.c` in the Python sources. New in version 2.4.

**CPython implementation detail:** This function is intimately bound to CPython implementation details and thus not likely to be implemented elsewhere.

`sys.stdin`

`sys.stdout`

`sys.stderr`

File objects corresponding to the interpreter's standard input, output and error streams. `stdin` is used for all interpreter input except for scripts but including calls to `input()` and `raw_input()`. `stdout` is used for the output of `print` and *expression* statements and for the prompts of `input()` and `raw_input()`. The interpreter's own prompts and (almost all of) its error messages go to `stderr`. `stdout` and `stderr` needn't be built-in file objects: any object is acceptable as long as it has a `write()` method that takes a string argument. (Changing these objects doesn't affect the standard I/O streams of processes executed by `os.popen()`, `os.system()` or the `exec*` family of functions in the `os` module.)

`sys.__stdin__`

`sys.__stdout__`

`sys.__stderr__`

These objects contain the original values of `stdin`, `stderr` and `stdout` at the start of the program. They are used during finalization, and could be useful to print to the actual standard stream no matter if the `sys.std*` object has been redirected.

It can also be used to restore the actual files to known working file objects in case they have been overwritten with a broken object. However, the preferred way to do this is to explicitly save the previous stream before replacing it, and restore the saved object.

`sys.subversion`

A triple (`repo`, `branch`, `version`) representing the Subversion information of the Python interpreter. *repo* is the name of the repository, 'CPython'. *branch* is a string of one of the forms 'trunk', 'branches/name' or 'tags/name'. *version* is the output of `svnversion`, if the interpreter was built from a Subversion

checkout; it contains the revision number (range) and possibly a trailing ‘M’ if there were local modifications. If the tree was exported (or `svnversion` was not available), it is the revision of `Include/patchlevel.h` if the branch is a tag. Otherwise, it is `None`. New in version 2.5.

---

**Note:** Python is now `developed` using Mercurial. In recent Python 2.7 bugfix releases, `subversion` therefore contains placeholder information. It is removed in Python 3.3.

---

### `sys.tracebacklimit`

When this variable is set to an integer value, it determines the maximum number of levels of traceback information printed when an unhandled exception occurs. The default is 1000. When set to 0 or less, all traceback information is suppressed and only the exception type and value are printed.

### `sys.version`

A string containing the version number of the Python interpreter plus additional information on the build number and compiler used. This string is displayed when the interactive interpreter is started. Do not extract version information out of it, rather, use `version_info` and the functions provided by the `platform` module.

### `sys.api_version`

The C API version for this interpreter. Programmers may find this useful when debugging version conflicts between Python and extension modules. New in version 2.3.

### `sys.version_info`

A tuple containing the five components of the version number: *major*, *minor*, *micro*, *releaselevel*, and *serial*. All values except *releaselevel* are integers; the release level is ‘alpha’, ‘beta’, ‘candidate’, or ‘final’. The `version_info` value corresponding to the Python version 2.0 is (2, 0, 0, ‘final’, 0). The components can also be accessed by name, so `sys.version_info[0]` is equivalent to `sys.version_info.major` and so on. New in version 2.0. Changed in version 2.7: Added named component attributes

### `sys.warnoptions`

This is an implementation detail of the warnings framework; do not modify this value. Refer to the `warnings` module for more information on the warnings framework.

### `sys.winver`

The version number used to form registry keys on Windows platforms. This is stored as string resource 1000 in the Python DLL. The value is normally the first three characters of `version`. It is provided in the `sys` module for informational purposes; modifying this value has no effect on the registry keys used by Python. Availability: Windows.

## Citations

## 27.2 `sysconfig` — Provide access to Python’s configuration information

New in version 2.7. **Source code:** [Lib/sysconfig.py](#)

---

The `sysconfig` module provides access to Python’s configuration information like the list of installation paths and the configuration variables relevant for the current platform.

## 27.2.1 Configuration variables

A Python distribution contains a `Makefile` and a `pyconfig.h` header file that are necessary to build both the Python binary itself and third-party C extensions compiled using `distutils`.

`sysconfig` puts all variables found in these files in a dictionary that can be accessed using `get_config_vars()` or `get_config_var()`.

Notice that on Windows, it's a much smaller set.

`sysconfig.get_config_vars(*args)`

With no arguments, return a dictionary of all configuration variables relevant for the current platform.

With arguments, return a list of values that result from looking up each argument in the configuration variable dictionary.

For each argument, if the value is not found, return `None`.

`sysconfig.get_config_var(name)`

Return the value of a single variable `name`. Equivalent to `get_config_vars().get(name)`.

If `name` is not found, return `None`.

Example of usage:

```
>>> import sysconfig
>>> sysconfig.get_config_var('Py_ENABLE_SHARED')
0
>>> sysconfig.get_config_var('LIBDIR')
'/usr/local/lib'
>>> sysconfig.get_config_vars('AR', 'CXX')
['ar', 'g++']
```

## 27.2.2 Installation paths

Python uses an installation scheme that differs depending on the platform and on the installation options. These schemes are stored in `sysconfig` under unique identifiers based on the value returned by `os.name`.

Every new component that is installed using `distutils` or a Distutils-based system will follow the same scheme to copy its file in the right places.

Python currently supports seven schemes:

- *posix\_prefix*: scheme for Posix platforms like Linux or Mac OS X. This is the default scheme used when Python or a component is installed.
- *posix\_home*: scheme for Posix platforms used when a *home* option is used upon installation. This scheme is used when a component is installed through Distutils with a specific home prefix.
- *posix\_user*: scheme for Posix platforms used when a component is installed through Distutils and the *user* option is used. This scheme defines paths located under the user home directory.
- *nt*: scheme for NT platforms like Windows.
- *nt\_user*: scheme for NT platforms, when the *user* option is used.
- *os2*: scheme for OS/2 platforms.
- *os2\_home*: scheme for OS/2 platforms, when the *user* option is used.

Each scheme is itself composed of a series of paths and each path has a unique identifier. Python currently uses eight paths:

- *stdlib*: directory containing the standard Python library files that are not platform-specific.
- *platstdlib*: directory containing the standard Python library files that are platform-specific.
- *platlib*: directory for site-specific, platform-specific files.
- *purelib*: directory for site-specific, non-platform-specific files.
- *include*: directory for non-platform-specific header files.
- *platinclude*: directory for platform-specific header files.
- *scripts*: directory for script files.
- *data*: directory for data files.

`sysconfig` provides some functions to determine these paths.

`sysconfig.get_scheme_names()`

Return a tuple containing all schemes currently supported in `sysconfig`.

`sysconfig.get_path_names()`

Return a tuple containing all path names currently supported in `sysconfig`.

`sysconfig.get_path(name[, scheme[, vars[, expand]]])`

Return an installation path corresponding to the path *name*, from the install scheme named *scheme*.

*name* has to be a value from the list returned by `get_path_names()`.

`sysconfig` stores installation paths corresponding to each path name, for each platform, with variables to be expanded. For instance the *stdlib* path for the *nt* scheme is: {base}/Lib.

`get_path()` will use the variables returned by `get_config_vars()` to expand the path. All variables have default values for each platform so one may call this function and get the default value.

If *scheme* is provided, it must be a value from the list returned by `get_scheme_names()`. Otherwise, the default scheme for the current platform is used.

If *vars* is provided, it must be a dictionary of variables that will update the dictionary return by `get_config_vars()`.

If *expand* is set to `False`, the path will not be expanded using the variables.

If *name* is not found, return `None`.

`sysconfig.get_paths([scheme[, vars[, expand]]])`

Return a dictionary containing all installation paths corresponding to an installation scheme. See `get_path()` for more information.

If *scheme* is not provided, will use the default scheme for the current platform.

If *vars* is provided, it must be a dictionary of variables that will update the dictionary used to expand the paths.

If *expand* is set to `False`, the paths will not be expanded.

If *scheme* is not an existing scheme, `get_paths()` will raise a `KeyError`.

### 27.2.3 Other functions

`sysconfig.get_python_version()`

Return the MAJOR.MINOR Python version number as a string. Similar to `sys.version[:3]`.

`sysconfig.get_platform()`

Return a string that identifies the current platform.

This is used mainly to distinguish platform-specific build directories and platform-specific built distributions. Typically includes the OS name and version and the architecture (as supplied by `os.uname()`), although the exact information included depends on the OS; e.g. for IRIX the architecture isn't particularly important (IRIX only runs on SGI hardware), but for Linux the kernel version isn't particularly important.

Examples of returned values:

- linux-i586
- linux-alpha (?)
- solaris-2.6-sun4u
- irix-5.3
- irix64-6.2

Windows will return one of:

- win-amd64 (64bit Windows on AMD64 (aka x86\_64, Intel64, EM64T, etc))
- win-ia64 (64bit Windows on Itanium)
- win32 (all others - specifically, `sys.platform` is returned)

Mac OS X can return:

- macosx-10.6-ppc
- macosx-10.4-ppc64
- macosx-10.3-i386
- macosx-10.4-fat

For other non-POSIX platforms, currently just returns `sys.platform`.

`sysconfig.is_python_build()`

Return True if the current Python installation was built from source.

`sysconfig.parse_config_h(fp[, vars])`

Parse a `config.h`-style file.

`fp` is a file-like object pointing to the `config.h`-like file.

A dictionary containing name/value pairs is returned. If an optional dictionary is passed in as the second argument, it is used instead of a new dictionary, and updated with the values read in the file.

`sysconfig.get_config_h_filename()`

Return the path of `pyconfig.h`.

## 27.3 `__builtin__` — Built-in objects

This module provides direct access to all 'built-in' identifiers of Python; for example, `__builtin__.open` is the full name for the built-in function `open()`. See *Built-in Functions* and *Built-in Constants* for documentation.

This module is not normally accessed explicitly by most applications, but can be useful in modules that provide objects with the same name as a built-in value, but in which the built-in of that name is also needed. For example, in a module that wants to implement an `open()` function that wraps the built-in `open()`, this module can be used directly:

```
import __builtin__

def open(path):
    f = __builtin__.open(path, 'r')
```

```
return UpperCaser(f)
```

```
class UpperCaser:
```

```
    '''Wrapper around a file that converts output to upper-case.'''
```

```
    def __init__(self, f):
        self._f = f
```

```
    def read(self, count=-1):
        return self._f.read(count).upper()
```

```
    # ...
```

**CPython implementation detail:** Most modules have the name `__builtins__` (note the 's') made available as part of their globals. The value of `__builtins__` is normally either this module or the value of this module's `__dict__` attribute. Since this is an implementation detail, it may not be used by alternate implementations of Python.

## 27.4 `future_builtins` — Python 3 builtins

New in version 2.6. This module provides functions that exist in 2.x, but have different behavior in Python 3, so they cannot be put into the 2.x builtins namespace.

Instead, if you want to write code compatible with Python 3 builtins, import them from this module, like this:

```
from future_builtins import map, filter
```

```
... code using Python 3-style map and filter ...
```

The *2to3* tool that ports Python 2 code to Python 3 will recognize this usage and leave the new builtins alone.

---

**Note:** The Python 3 `print()` function is already in the builtins, but cannot be accessed from Python 2 code unless you use the appropriate future statement:

```
from __future__ import print_function
```

---

Available builtins are:

`future_builtins.ascii` (*object*)

Returns the same as `repr()`. In Python 3, `repr()` will return printable Unicode characters unescaped, while `ascii()` will always backslash-escape them. Using `future_builtins.ascii()` instead of `repr()` in 2.6 code makes it clear that you need a pure ASCII return value.

`future_builtins.filter` (*function, iterable*)

Works like `itertools.ifilter()`.

`future_builtins.hex` (*object*)

Works like the built-in `hex()`, but instead of `__hex__()` it will use the `__index__()` method on its argument to get an integer that is then converted to hexadecimal.

`future_builtins.map` (*function, iterable, ...*)

Works like `itertools.imap()`.

`future_builtins.oct` (*object*)

Works like the built-in `oct()`, but instead of `__oct__()` it will use the `__index__()` method on its argument to get an integer that is then converted to octal.

```
future_builtins.zip(*iterables)
    Works like itertools.izip().
```

## 27.5 `__main__` — Top-level script environment

This module represents the (otherwise anonymous) scope in which the interpreter’s main program executes — commands read either from standard input, from a script file, or from an interactive prompt. It is this environment in which the idiomatic “conditional script” stanza causes a script to run:

```
if __name__ == "__main__":
    main()
```

## 27.6 warnings — Warning control

New in version 2.1. **Source code:** [Lib/warnings.py](#)

Warning messages are typically issued in situations where it is useful to alert the user of some condition in a program, where that condition (normally) doesn’t warrant raising an exception and terminating the program. For example, one might want to issue a warning when a program uses an obsolete module.

Python programmers issue warnings by calling the `warn()` function defined in this module. (C programmers use `PyErr_WarnEx()`; see *exceptionhandling* for details).

Warning messages are normally written to `sys.stderr`, but their disposition can be changed flexibly, from ignoring all warnings to turning them into exceptions. The disposition of warnings can vary based on the warning category (see below), the text of the warning message, and the source location where it is issued. Repetitions of a particular warning for the same source location are typically suppressed.

There are two stages in warning control: first, each time a warning is issued, a determination is made whether a message should be issued or not; next, if a message is to be issued, it is formatted and printed using a user-settable hook.

The determination whether to issue a warning message is controlled by the warning filter, which is a sequence of matching rules and actions. Rules can be added to the filter by calling `filterwarnings()` and reset to its default state by calling `resetwarnings()`.

The printing of warning messages is done by calling `showwarning()`, which may be overridden; the default implementation of this function formats the message by calling `formatwarning()`, which is also available for use by custom implementations.

### See Also:

`logging.captureWarnings()` allows you to handle all warnings with the standard logging infrastructure.

### 27.6.1 Warning Categories

There are a number of built-in exceptions that represent warning categories. This categorization is useful to be able to filter out groups of warnings. The following warnings category classes are currently defined:

Class	Description
<code>Warning</code>	This is the base class of all warning category classes. It is a subclass of <code>Exception</code> .
<code>UserWarning</code>	The default category for <code>warn()</code> .
<code>DeprecationWarning</code>	Base category for warnings about deprecated features (ignored by default).
<code>SyntaxWarning</code>	Base category for warnings about dubious syntactic features.
<code>RuntimeWarning</code>	Base category for warnings about dubious runtime features.
<code>FutureWarning</code>	Base category for warnings about constructs that will change semantically in the future.
<code>PendingDeprecationWarning</code>	Base category for warnings about features that will be deprecated in the future (ignored by default).
<code>ImportWarning</code>	Base category for warnings triggered during the process of importing a module (ignored by default).
<code>UnicodeWarning</code>	Base category for warnings related to Unicode.

While these are technically built-in exceptions, they are documented here, because conceptually they belong to the warnings mechanism.

User code can define additional warning categories by subclassing one of the standard warning categories. A warning category must always be a subclass of the `Warning` class. Changed in version 2.7: `DeprecationWarning` is ignored by default.

## 27.6.2 The Warnings Filter

The warnings filter controls whether warnings are ignored, displayed, or turned into errors (raising an exception).

Conceptually, the warnings filter maintains an ordered list of filter specifications; any specific warning is matched against each filter specification in the list in turn until a match is found; the match determines the disposition of the match. Each entry is a tuple of the form *(action, message, category, module, lineno)*, where:

- action* is one of the following strings:

Value	Disposition
"error"	turn matching warnings into exceptions
"ignore"	never print matching warnings
"always"	always print matching warnings
"default"	print the first occurrence of matching warnings for each location where the warning is issued
"module"	print the first occurrence of matching warnings for each module where the warning is issued
"once"	print only the first occurrence of matching warnings, regardless of location

- message* is a string containing a regular expression that the warning message must match (the match is compiled to always be case-insensitive).
- category* is a class (a subclass of `Warning`) of which the warning category must be a subclass in order to match.
- module* is a string containing a regular expression that the module name must match (the match is compiled to be case-sensitive).
- lineno* is an integer that the line number where the warning occurred must match, or 0 to match all line numbers.

Since the `Warning` class is derived from the built-in `Exception` class, to turn a warning into an error we simply raise `category(message)`.

The warnings filter is initialized by `-W` options passed to the Python interpreter command line. The interpreter saves the arguments for all `-W` options without interpretation in `sys.warnoptions`; the `warnings` module parses these when it is first imported (invalid options are ignored, after printing a message to `sys.stderr`).

## Default Warning Filters

By default, Python installs several warning filters, which can be overridden by the command-line options passed to `-W` and calls to `filterwarnings()`.

- `DeprecationWarning` and `PendingDeprecationWarning`, and `ImportWarning` are ignored.
- `BytesWarning` is ignored unless the `-b` option is given once or twice; in this case this warning is either printed (`-b`) or turned into an exception (`-bb`).

### 27.6.3 Temporarily Suppressing Warnings

If you are using code that you know will raise a warning, such as a deprecated function, but do not want to see the warning, then it is possible to suppress the warning using the `catch_warnings` context manager:

```
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings():
    warnings.simplefilter("ignore")
    fxn()
```

While within the context manager all warnings will simply be ignored. This allows you to use known-deprecated code without having to see the warning while not suppressing the warning for other code that might not be aware of its use of deprecated code. Note: this can only be guaranteed in a single-threaded application. If two or more threads use the `catch_warnings` context manager at the same time, the behavior is undefined.

### 27.6.4 Testing Warnings

To test warnings raised by code, use the `catch_warnings` context manager. With it you can temporarily mutate the warnings filter to facilitate your testing. For instance, do the following to capture all raised warnings to check:

```
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings(record=True) as w:
    # Cause all warnings to always be triggered.
    warnings.simplefilter("always")
    # Trigger a warning.
    fxn()
    # Verify some things
    assert len(w) == 1
    assert isinstance(w[-1].category, DeprecationWarning)
    assert "deprecated" in str(w[-1].message)
```

One can also cause all warnings to be exceptions by using `error` instead of `always`. One thing to be aware of is that if a warning has already been raised because of a `once/default` rule, then no matter what filters are set the warning will not be seen again unless the warnings registry related to the warning has been cleared.

Once the context manager exits, the warnings filter is restored to its state when the context was entered. This prevents tests from changing the warnings filter in unexpected ways between tests and leading to indeterminate test results. The `showwarning()` function in the module is also restored to its original value. Note: this can only be guaranteed in

a single-threaded application. If two or more threads use the `catch_warnings` context manager at the same time, the behavior is undefined.

When testing multiple operations that raise the same kind of warning, it is important to test them in a manner that confirms each operation is raising a new warning (e.g. set warnings to be raised as exceptions and check the operations raise exceptions, check that the length of the warning list continues to increase after each operation, or else delete the previous entries from the warnings list before each new operation).

### 27.6.5 Updating Code For New Versions of Python

Warnings that are only of interest to the developer are ignored by default. As such you should make sure to test your code with typically ignored warnings made visible. You can do this from the command-line by passing `-Wd` to the interpreter (this is shorthand for `-W default`). This enables default handling for all warnings, including those that are ignored by default. To change what action is taken for encountered warnings you simply change what argument is passed to `-W`, e.g. `-W error`. See the `-W` flag for more details on what is possible.

To programmatically do the same as `-Wd`, use:

```
warnings.simplefilter('default')
```

Make sure to execute this code as soon as possible. This prevents the registering of what warnings have been raised from unexpectedly influencing how future warnings are treated.

Having certain warnings ignored by default is done to prevent a user from seeing warnings that are only of interest to the developer. As you do not necessarily have control over what interpreter a user uses to run their code, it is possible that a new version of Python will be released between your release cycles. The new interpreter release could trigger new warnings in your code that were not there in an older interpreter, e.g. `DeprecationWarning` for a module that you are using. While you as a developer want to be notified that your code is using a deprecated module, to a user this information is essentially noise and provides no benefit to them.

### 27.6.6 Available Functions

```
warnings.warn(message[, category[, stacklevel]])
```

Issue a warning, or maybe ignore it or raise an exception. The `category` argument, if given, must be a warning category class (see above); it defaults to `UserWarning`. Alternatively `message` can be a `Warning` instance, in which case `category` will be ignored and `message.__class__` will be used. In this case the message text will be `str(message)`. This function raises an exception if the particular warning issued is changed into an error by the warnings filter see above. The `stacklevel` argument can be used by wrapper functions written in Python, like this:

```
def deprecation(message):
    warnings.warn(message, DeprecationWarning, stacklevel=2)
```

This makes the warning refer to `deprecation()`'s caller, rather than to the source of `deprecation()` itself (since the latter would defeat the purpose of the warning message).

```
warnings.warn_explicit(message, category, filename, lineno[, module[, registry[, module_globals]]])
```

This is a low-level interface to the functionality of `warn()`, passing in explicitly the message, category, filename and line number, and optionally the module name and the registry (which should be the `__warningregistry__` dictionary of the module). The module name defaults to the filename with `.py` stripped; if no registry is passed, the warning is never suppressed. `message` must be a string and `category` a subclass of `Warning` or `message` may be a `Warning` instance, in which case `category` will be ignored.

*module\_globals*, if supplied, should be the global namespace in use by the code for which the warning is issued. (This argument is used to support displaying source for modules found in zipfiles or other non-filesystem import sources). Changed in version 2.5: Added the *module\_globals* parameter.

`warnings.warnpy3k(message[, category[, stacklevel]])`

Issue a warning related to Python 3.x deprecation. Warnings are only shown when Python is started with the `-3` option. Like `warn()` *message* must be a string and *category* a subclass of `Warning`. `warnpy3k()` is using `DeprecationWarning` as default warning class. New in version 2.6.

`warnings.showwarning(message, category, filename, lineno[, file[, line]])`

Write a warning to a file. The default implementation calls `formatwarning(message, category, filename, lineno, line)` and writes the resulting string to *file*, which defaults to `sys.stderr`. You may replace this function with an alternative implementation by assigning to `warnings.showwarning`. *line* is a line of source code to be included in the warning message; if *line* is not supplied, `showwarning()` will try to read the line specified by *filename* and *lineno*. Changed in version 2.7: The *line* argument is required to be supported.

`warnings.formatwarning(message, category, filename, lineno[, line])`

Format a warning the standard way. This returns a string which may contain embedded newlines and ends in a newline. *line* is a line of source code to be included in the warning message; if *line* is not supplied, `formatwarning()` will try to read the line specified by *filename* and *lineno*. Changed in version 2.6: Added the *line* argument.

`warnings.filterwarnings(action[, message[, category[, module[, lineno[, append]]]])`

Insert an entry into the list of *warnings filter specifications*. The entry is inserted at the front by default; if *append* is true, it is inserted at the end. This checks the types of the arguments, compiles the *message* and *module* regular expressions, and inserts them as a tuple in the list of warnings filters. Entries closer to the front of the list override entries later in the list, if both match a particular warning. Omitted arguments default to a value that matches everything.

`warnings.simplefilter(action[, category[, lineno[, append]])`

Insert a simple entry into the list of *warnings filter specifications*. The meaning of the function parameters is as for `filterwarnings()`, but regular expressions are not needed as the filter inserted always matches any message in any module as long as the category and line number match.

`warnings.resetwarnings()`

Reset the warnings filter. This discards the effect of all previous calls to `filterwarnings()`, including that of the `-W` command line options and calls to `simplefilter()`.

## 27.6.7 Available Context Managers

`class warnings.catch_warnings([*, record=False, module=None])`

A context manager that copies and, upon exit, restores the warnings filter and the `showwarning()` function. If the *record* argument is `False` (the default) the context manager returns `None` on entry. If *record* is `True`, a list is returned that is progressively populated with objects as seen by a custom `showwarning()` function (which also suppresses output to `sys.stdout`). Each object in the list has attributes with the same names as the arguments to `showwarning()`.

The *module* argument takes a module that will be used instead of the module returned when you import `warnings` whose filter will be protected. This argument exists primarily for testing the `warnings` module itself.

---

**Note:** The `catch_warnings` manager works by replacing and then later restoring the module's `showwarning()` function and internal list of filter specifications. This means the context manager is modifying global state and therefore is not thread-safe.

---

---

**Note:** In Python 3, the arguments to the constructor for `catch_warnings` are keyword-only arguments.

---

New in version 2.6.

## 27.7 contextlib — Utilities for with-statement contexts

New in version 2.5. **Source code:** [Lib/contextlib.py](#)

---

This module provides utilities for common tasks involving the `with` statement. For more information see also *Context Manager Types* and *context-managers*.

Functions provided:

`contextlib.contextmanager` (*func*)

This function is a *decorator* that can be used to define a factory function for `with` statement context managers, without needing to create a class or separate `__enter__()` and `__exit__()` methods.

A simple example (this is not recommended as a real way of generating HTML!):

```
from contextlib import contextmanager
```

```
@contextmanager
def tag(name):
    print "<%s>" % name
    yield
    print "</%s>" % name
```

```
>>> with tag("h1"):
...     print "foo"
...
<h1>
foo
</h1>
```

The function being decorated must return a *generator*-iterator when called. This iterator must yield exactly one value, which will be bound to the targets in the `with` statement's `as` clause, if any.

At the point where the generator yields, the block nested in the `with` statement is executed. The generator is then resumed after the block is exited. If an unhandled exception occurs in the block, it is reraised inside the generator at the point where the `yield` occurred. Thus, you can use a `try...except...finally` statement to trap the error (if any), or ensure that some cleanup takes place. If an exception is trapped merely in order to log it or to perform some action (rather than to suppress it entirely), the generator must reraise that exception. Otherwise the generator context manager will indicate to the `with` statement that the exception has been handled, and execution will resume with the statement immediately following the `with` statement.

`contextlib.nested` (*mgr1*[, *mgr2*[, ... ]])

Combine multiple context managers into a single nested context manager.

This function has been deprecated in favour of the multiple manager form of the `with` statement.

The one advantage of this function over the multiple manager form of the `with` statement is that argument unpacking allows it to be used with a variable number of context managers as follows:

```

from contextlib import nested

with nested(*managers):
    do_something()

```

Note that if the `__exit__()` method of one of the nested context managers indicates an exception should be suppressed, no exception information will be passed to any remaining outer context managers. Similarly, if the `__exit__()` method of one of the nested managers raises an exception, any previous exception state will be lost; the new exception will be passed to the `__exit__()` methods of any remaining outer context managers. In general, `__exit__()` methods should avoid raising exceptions, and in particular they should not re-raise a passed-in exception.

This function has two major quirks that have led to it being deprecated. Firstly, as the context managers are all constructed before the function is invoked, the `__new__()` and `__init__()` methods of the inner context managers are not actually covered by the scope of the outer context managers. That means, for example, that using `nested()` to open two files is a programming error as the first file will not be closed promptly if an exception is thrown when opening the second file.

Secondly, if the `__enter__()` method of one of the inner context managers raises an exception that is caught and suppressed by the `__exit__()` method of one of the outer context managers, this construct will raise `RuntimeError` rather than skipping the body of the `with` statement.

Developers that need to support nesting of a variable number of context managers can either use the `warnings` module to suppress the `DeprecationWarning` raised by this function or else use this function as a model for an application specific implementation. Deprecated since version 2.7: The `with`-statement now supports this functionality directly (without the confusing error prone quirks).

`contextlib.closing(thing)`

Return a context manager that closes *thing* upon completion of the block. This is basically equivalent to:

```

from contextlib import contextmanager

@contextmanager
def closing(thing):
    try:
        yield thing
    finally:
        thing.close()

```

And lets you write code like this:

```

from contextlib import closing
import urllib

with closing(urllib.urlopen('http://www.python.org')) as page:
    for line in page:
        print line

```

without needing to explicitly close `page`. Even if an error occurs, `page.close()` will be called when the `with` block is exited.

**See Also:**

**PEP 0343 - The “with” statement** The specification, background, and examples for the Python `with` statement.

## 27.8 abc — Abstract Base Classes

New in version 2.6. **Source code:** [Lib/abc.py](#)

---

This module provides the infrastructure for defining *abstract base classes* (ABCs) in Python, as outlined in [PEP 3119](#); see the PEP for why this was added to Python. (See also [PEP 3141](#) and the `numbers` module regarding a type hierarchy for numbers based on ABCs.)

The `collections` module has some concrete classes that derive from ABCs; these can, of course, be further derived. In addition the `collections` module has some ABCs that can be used to test whether a class or instance provides a particular interface, for example, is it hashable or a mapping.

This module provides the following class:

**class** `abc.ABCMeta`

Metaclass for defining Abstract Base Classes (ABCs).

Use this metaclass to create an ABC. An ABC can be subclassed directly, and then acts as a mix-in class. You can also register unrelated concrete classes (even built-in classes) and unrelated ABCs as “virtual subclasses” – these and their descendants will be considered subclasses of the registering ABC by the built-in `issubclass()` function, but the registering ABC won’t show up in their MRO (Method Resolution Order) nor will method implementations defined by the registering ABC be callable (not even via `super()`).<sup>1</sup>

Classes created with a metaclass of `ABCMeta` have the following method:

**register** (*subclass*)

Register *subclass* as a “virtual subclass” of this ABC. For example:

```
from abc import ABCMeta

class MyABC:
    __metaclass__ = ABCMeta

MyABC.register(tuple)

assert issubclass(tuple, MyABC)
assert isinstance((), MyABC)
```

You can also override this method in an abstract base class:

**\_\_subclasshook\_\_** (*subclass*)

(Must be defined as a class method.)

Check whether *subclass* is considered a subclass of this ABC. This means that you can customize the behavior of `issubclass` further without the need to call `register()` on every class you want to consider a subclass of the ABC. (This class method is called from the `__subclasscheck__()` method of the ABC.)

This method should return `True`, `False` or `NotImplemented`. If it returns `True`, the *subclass* is considered a subclass of this ABC. If it returns `False`, the *subclass* is not considered a subclass of this ABC, even if it would normally be one. If it returns `NotImplemented`, the subclass check is continued with the usual mechanism.

For a demonstration of these concepts, look at this example ABC definition:

---

<sup>1</sup> C++ programmers should note that Python’s virtual base class concept is not the same as C++’s.

```

class Foo(object):
    def __getitem__(self, index):
        ...
    def __len__(self):
        ...
    def get_iterator(self):
        return iter(self)

class MyIterable:
    __metaclass__ = ABCMeta

    @abstractmethod
    def __iter__(self):
        while False:
            yield None

    def get_iterator(self):
        return self.__iter__()

    @classmethod
    def __subclasshook__(cls, C):
        if cls is MyIterable:
            if any("__iter__" in B.__dict__ for B in C.__mro__):
                return True
            return NotImplemented

```

```
MyIterable.register(Foo)
```

The ABC `MyIterable` defines the standard iterable method, `__iter__()`, as an abstract method. The implementation given here can still be called from subclasses. The `get_iterator()` method is also part of the `MyIterable` abstract base class, but it does not have to be overridden in non-abstract derived classes.

The `__subclasshook__()` class method defined here says that any class that has an `__iter__()` method in its `__dict__` (or in that of one of its base classes, accessed via the `__mro__` list) is considered a `MyIterable` too.

Finally, the last line makes `Foo` a virtual subclass of `MyIterable`, even though it does not define an `__iter__()` method (it uses the old-style iterable protocol, defined in terms of `__len__()` and `__getitem__()`). Note that this will not make `get_iterator` available as a method of `Foo`, so it is provided separately.

It also provides the following decorators:

`abc.abstractmethod` (*function*)

A decorator indicating abstract methods.

Using this decorator requires that the class's metaclass is `ABCMeta` or is derived from it. A class that has a metaclass derived from `ABCMeta` cannot be instantiated unless all of its abstract methods and properties are overridden. The abstract methods can be called using any of the normal 'super' call mechanisms.

Dynamically adding abstract methods to a class, or attempting to modify the abstraction status of a method or class once it is created, are not supported. The `abstractmethod()` only affects subclasses derived using regular inheritance; "virtual subclasses" registered with the ABC's `register()` method are not affected.

Usage:

```
class C:
```

```
__metaclass__ = ABCMeta
@abstractmethod
def my_abstract_method(self, ...):
    ...
```

---

**Note:** Unlike Java abstract methods, these abstract methods may have an implementation. This implementation can be called via the `super()` mechanism from the class that overrides it. This could be useful as an end-point for a super-call in a framework that uses cooperative multiple-inheritance.

---

abc. **abstractproperty** (`[fget[, fset[, fdel[, doc]]]]`)

A subclass of the built-in `property()`, indicating an abstract property.

Using this function requires that the class's metaclass is `ABCMeta` or is derived from it. A class that has a metaclass derived from `ABCMeta` cannot be instantiated unless all of its abstract methods and properties are overridden. The abstract properties can be called using any of the normal 'super' call mechanisms.

Usage:

```
class C:
    __metaclass__ = ABCMeta
    @abstractproperty
    def my_abstract_property(self):
        ...
```

This defines a read-only property; you can also define a read-write abstract property using the 'long' form of property declaration:

```
class C:
    __metaclass__ = ABCMeta
    def getx(self): ...
    def setx(self, value): ...
    x = abstractproperty(getx, setx)
```

## 27.9 atexit — Exit handlers

New in version 2.0. **Source code:** `Lib/atexit.py`

---

The `atexit` module defines a single function to register cleanup functions. Functions thus registered are automatically executed upon normal interpreter termination. The order in which the functions are called is not defined; if you have cleanup operations that depend on each other, you should wrap them in a function and register that one. This keeps `atexit` simple.

Note: the functions registered via this module are not called when the program is killed by a signal not handled by Python, when a Python fatal internal error is detected, or when `os._exit()` is called.

This is an alternate interface to the functionality provided by the `sys.exitfunc()` variable.

Note: This module is unlikely to work correctly when used with other code that sets `sys.exitfunc`. In particular, other core Python modules are free to use `atexit` without the programmer's knowledge. Authors who use `sys.exitfunc` should convert their code to use `atexit` instead. The simplest way to convert code that sets `sys.exitfunc` is to import `atexit` and register the function that had been bound to `sys.exitfunc`.

`atexit.register(func[, *args[, **kwargs]])`

Register *func* as a function to be executed at termination. Any optional arguments that are to be passed to *func* must be passed as arguments to `register()`. It is possible to register the same function and arguments more than once.

At normal program termination (for instance, if `sys.exit()` is called or the main module's execution completes), all functions registered are called in last in, first out order. The assumption is that lower level modules will normally be imported before higher level modules and thus must be cleaned up later.

If an exception is raised during execution of the exit handlers, a traceback is printed (unless `SystemExit` is raised) and the exception information is saved. After all exit handlers have had a chance to run the last exception to be raised is re-raised. Changed in version 2.6: This function now returns *func*, which makes it possible to use it as a decorator.

#### See Also:

**Module `readline`** Useful example of `atexit` to read and write `readline` history files.

## 27.9.1 `atexit` Example

The following simple example demonstrates how a module can initialize a counter from a file when it is imported and save the counter's updated value automatically when the program terminates without relying on the application making an explicit call into this module at termination.

```
try:
    _count = int(open("/tmp/counter").read())
except IOError:
    _count = 0

def incrcounter(n):
    global _count
    _count = _count + n

def savecounter():
    open("/tmp/counter", "w").write("%d" % _count)

import atexit
atexit.register(savecounter)
```

Positional and keyword arguments may also be passed to `register()` to be passed along to the registered function when it is called:

```
def goodbye(name, adjective):
    print 'Goodbye, %s, it was %s to meet you.' % (name, adjective)

import atexit
atexit.register(goodbye, 'Donny', 'nice')

# or:
atexit.register(goodbye, adjective='nice', name='Donny')
```

Usage as a *decorator*:

```
import atexit

@atexit.register
def goodbye():
    print "You are now leaving the Python sector."
```

This only works with functions that can be called without arguments.

## 27.10 `traceback` — Print or retrieve a stack traceback

This module provides a standard interface to extract, format and print stack traces of Python programs. It exactly mimics the behavior of the Python interpreter when it prints a stack trace. This is useful when you want to print stack traces under program control, such as in a “wrapper” around the interpreter.

The module uses traceback objects — this is the object type that is stored in the variables `sys.exc_traceback` (deprecated) and `sys.last_traceback` and returned as the third item from `sys.exc_info()`.

The module defines the following functions:

`traceback.print_tb` (*traceback* [, *limit* [, *file* ]])

Print up to *limit* stack trace entries from *traceback*. If *limit* is omitted or `None`, all entries are printed. If *file* is omitted or `None`, the output goes to `sys.stderr`; otherwise it should be an open file or file-like object to receive the output.

`traceback.print_exception` (*type*, *value*, *traceback* [, *limit* [, *file* ]])

Print exception information and up to *limit* stack trace entries from *traceback* to *file*. This differs from `print_tb()` in the following ways: (1) if *traceback* is not `None`, it prints a header `Traceback (most recent call last):`; (2) it prints the exception *type* and *value* after the stack trace; (3) if *type* is `SyntaxError` and *value* has the appropriate format, it prints the line where the syntax error occurred with a caret indicating the approximate position of the error.

`traceback.print_exc` ([*limit* [, *file* ]])

This is a shorthand for `print_exception(sys.exc_type, sys.exc_value, sys.exc_traceback, limit, file)`. (In fact, it uses `sys.exc_info()` to retrieve the same information in a thread-safe way instead of using the deprecated variables.)

`traceback.format_exc` ([*limit*])

This is like `print_exc(limit)` but returns a string instead of printing to a file. New in version 2.4.

`traceback.print_last` ([*limit* [, *file* ]])

This is a shorthand for `print_exception(sys.last_type, sys.last_value, sys.last_traceback, limit, file)`. In general it will work only after an exception has reached an interactive prompt (see `sys.last_type`).

`traceback.print_stack` ([*f* [, *limit* [, *file* ]]])

This function prints a stack trace from its invocation point. The optional *f* argument can be used to specify an alternate stack frame to start. The optional *limit* and *file* arguments have the same meaning as for `print_exception()`.

`traceback.extract_tb` (*traceback* [, *limit*])

Return a list of up to *limit* “pre-processed” stack trace entries extracted from the traceback object *traceback*. It is useful for alternate formatting of stack traces. If *limit* is omitted or `None`, all entries are extracted. A “pre-processed” stack trace entry is a quadruple (*filename*, *line number*, *function name*, *text*) representing the information that is usually printed for a stack trace. The *text* is a string with leading and trailing whitespace stripped; if the source is not available it is `None`.

`traceback.extract_stack` ([*f* [, *limit* ]])

Extract the raw traceback from the current stack frame. The return value has the same format as for `extract_tb()`. The optional *f* and *limit* arguments have the same meaning as for `print_stack()`.

`traceback.format_list` (*list*)

Given a list of tuples as returned by `extract_tb()` or `extract_stack()`, return a list of strings ready for printing. Each string in the resulting list corresponds to the item with the same index in the argument list.

Each string ends in a newline; the strings may contain internal newlines as well, for those items whose source text line is not None.

`traceback.format_exception_only` (*type*, *value*)

Format the exception part of a traceback. The arguments are the exception type and value such as given by `sys.last_type` and `sys.last_value`. The return value is a list of strings, each ending in a newline. Normally, the list contains a single string; however, for `SyntaxError` exceptions, it contains several lines that (when printed) display detailed information about where the syntax error occurred. The message indicating which exception occurred is the always last string in the list.

`traceback.format_exception` (*type*, *value*, *tb* [, *limit*])

Format a stack trace and the exception information. The arguments have the same meaning as the corresponding arguments to `print_exception()`. The return value is a list of strings, each ending in a newline and some containing internal newlines. When these lines are concatenated and printed, exactly the same text is printed as does `print_exception()`.

`traceback.format_tb` (*tb* [, *limit*])

A shorthand for `format_list(extract_tb(tb, limit))`.

`traceback.format_stack` (*f* [, *limit*])

A shorthand for `format_list(extract_stack(f, limit))`.

`traceback.tb_lineno` (*tb*)

This function returns the current line number set in the traceback object. This function was necessary because in versions of Python prior to 2.3 when the `-O` flag was passed to Python the `tb.tb_lineno` was not updated correctly. This function has no use in versions past 2.3.

## 27.10.1 Traceback Examples

This simple example implements a basic read-eval-print loop, similar to (but less useful than) the standard Python interactive interpreter loop. For a more complete implementation of the interpreter loop, refer to the `code` module.

```
import sys, traceback

def run_user_code(envdir):
    source = raw_input(">>> ")
    try:
        exec source in envdir
    except:
        print "Exception in user code:"
        print '-' * 60
        traceback.print_exc(file=sys.stdout)
        print '-' * 60

envdir = {}
while 1:
    run_user_code(envdir)
```

The following example demonstrates the different ways to print and format the exception and traceback:

```
import sys, traceback

def lumberjack():
    bright_side_of_death()

def bright_side_of_death():
    return tuple()[0]
```

```
try:
    lumberjack()
except IndexError:
    exc_type, exc_value, exc_traceback = sys.exc_info()
    print "*** print_tb:"
    traceback.print_tb(exc_traceback, limit=1, file=sys.stdout)
    print "*** print_exception:"
    traceback.print_exception(exc_type, exc_value, exc_traceback,
                              limit=2, file=sys.stdout)

    print "*** print_exc:"
    traceback.print_exc()
    print "*** format_exc, first and last line:"
    formatted_lines = traceback.format_exc().splitlines()
    print formatted_lines[0]
    print formatted_lines[-1]
    print "*** format_exception:"
    print repr(traceback.format_exception(exc_type, exc_value,
                                         exc_traceback))

    print "*** extract_tb:"
    print repr(traceback.extract_tb(exc_traceback))
    print "*** format_tb:"
    print repr(traceback.format_tb(exc_traceback))
    print "*** tb_lineno:", exc_traceback.tb_lineno
```

The output for the example would look similar to this:

```
*** print_tb:
  File "<doctest...>", line 10, in <module>
    lumberjack()
*** print_exception:
Traceback (most recent call last):
  File "<doctest...>", line 10, in <module>
    lumberjack()
  File "<doctest...>", line 4, in lumberjack
    bright_side_of_death()
IndexError: tuple index out of range
*** print_exc:
Traceback (most recent call last):
  File "<doctest...>", line 10, in <module>
    lumberjack()
  File "<doctest...>", line 4, in lumberjack
    bright_side_of_death()
IndexError: tuple index out of range
*** format_exc, first and last line:
Traceback (most recent call last):
IndexError: tuple index out of range
*** format_exception:
['Traceback (most recent call last):\n',
 '  File "<doctest...>", line 10, in <module>\n    lumberjack()\n',
 '  File "<doctest...>", line 4, in lumberjack\n    bright_side_of_death()\n',
 '  File "<doctest...>", line 7, in bright_side_of_death\n    return tuple()[0]\n',
 'IndexError: tuple index out of range\n']
*** extract_tb:
[('<doctest...>', 10, '<module>', 'lumberjack()'),
```

```

('<doctest...>', 4, 'lumberjack', 'bright_side_of_death()'),
('<doctest...>', 7, 'bright_side_of_death', 'return tuple()[0]')]
*** format_tb:
[' File "<doctest...>", line 10, in <module>\n    lumberjack()\n',
 ' File "<doctest...>", line 4, in lumberjack\n    bright_side_of_death()\n',
 ' File "<doctest...>", line 7, in bright_side_of_death\n    return tuple()[0]\n']
*** tb_lineno: 10

```

The following example shows the different ways to print and format the stack:

```

>>> import traceback
>>> def another_function():
...     lumberstack()
...
>>> def lumberstack():
...     traceback.print_stack()
...     print repr(traceback.extract_stack())
...     print repr(traceback.format_stack())
...
>>> another_function()
File "<doctest>", line 10, in <module>
  another_function()
File "<doctest>", line 3, in another_function
  lumberstack()
File "<doctest>", line 6, in lumberstack
  traceback.print_stack()
(['<doctest>', 10, '<module>', 'another_function()'),
 ('<doctest>', 3, 'another_function', 'lumberstack()'),
 ('<doctest>', 7, 'lumberstack', 'print repr(traceback.extract_stack())')]
[' File "<doctest>", line 10, in <module>\n    another_function()\n',
 ' File "<doctest>", line 3, in another_function\n    lumberstack()\n',
 ' File "<doctest>", line 8, in lumberstack\n    print repr(traceback.format_stack())\n']

```

This last example demonstrates the final few formatting functions:

```

>>> import traceback
>>> traceback.format_list([('spam.py', 3, '<module>', 'spam.eggs()'),
...                       ('eggs.py', 42, 'eggs', 'return "bacon"')])
[' File "spam.py", line 3, in <module>\n    spam.eggs()\n',
 ' File "eggs.py", line 42, in eggs\n    return "bacon"\n']
>>> an_error = IndexError('tuple index out of range')
>>> traceback.format_exception_only(type(an_error), an_error)
['IndexError: tuple index out of range\n']

```

## 27.11 `__future__` — Future statement definitions

Source code: `Lib/__future__.py`

`__future__` is a real module, and serves three purposes:

- To avoid confusing existing tools that analyze import statements and expect to find the modules they're importing.

- To ensure that *future statements* run under releases prior to 2.1 at least yield runtime exceptions (the import of `__future__` will fail, because there was no module of that name prior to 2.1).
- To document when incompatible changes were introduced, and when they will be — or were — made mandatory. This is a form of executable documentation, and can be inspected programmatically via importing `__future__` and examining its contents.

Each statement in `__future__.py` is of the form:

```
FeatureName = _Feature(OptionalRelease, MandatoryRelease,
                      CompilerFlag)
```

where, normally, *OptionalRelease* is less than *MandatoryRelease*, and both are 5-tuples of the same form as `sys.version_info`:

```
(PY_MAJOR_VERSION, # the 2 in 2.1.0a3; an int
 PY_MINOR_VERSION, # the 1; an int
 PY_MICRO_VERSION, # the 0; an int
 PY_RELEASE_LEVEL, # "alpha", "beta", "candidate" or "final"; string
 PY_RELEASE_SERIAL # the 3; an int
)
```

*OptionalRelease* records the first release in which the feature was accepted.

In the case of a *MandatoryRelease* that has not yet occurred, *MandatoryRelease* predicts the release in which the feature will become part of the language.

Else *MandatoryRelease* records when the feature became part of the language; in releases at or after that, modules no longer need a future statement to use the feature in question, but may continue to use such imports.

*MandatoryRelease* may also be `None`, meaning that a planned feature got dropped.

Instances of class `_Feature` have two corresponding methods, `getOptionalRelease()` and `getMandatoryRelease()`.

*CompilerFlag* is the (bitfield) flag that should be passed in the fourth argument to the built-in function `compile()` to enable the feature in dynamically compiled code. This flag is stored in the `compiler_flag` attribute on `_Feature` instances.

No feature description will ever be deleted from `__future__`. Since its introduction in Python 2.1 the following features have found their way into the language using this mechanism:

feature	optional in	mandatory in	effect
nested_scopes	2.1.0b1	2.2	<b>PEP 227</b> : <i>Statically Nested Scopes</i>
generators	2.2.0a1	2.3	<b>PEP 255</b> : <i>Simple Generators</i>
division	2.2.0a2	3.0	<b>PEP 238</b> : <i>Changing the Division Operator</i>
absolute_import	2.5.0a1	3.0	<b>PEP 328</b> : <i>Imports: Multi-Line and Absolute/Relative</i>
with_statement	2.5.0a1	2.6	<b>PEP 343</b> : <i>The “with” Statement</i>
print_function	2.6.0a2	3.0	<b>PEP 3105</b> : <i>Make print a function</i>
unicode_literals	2.6.0a2	3.0	<b>PEP 3112</b> : <i>Bytes literals in Python 3000</i>

**See Also:**

*future* How the compiler treats future imports.

## 27.12 gc — Garbage Collector interface

This module provides an interface to the optional garbage collector. It provides the ability to disable the collector, tune the collection frequency, and set debugging options. It also provides access to unreachable objects that the collector found but cannot free. Since the collector supplements the reference counting already used in Python, you can disable the collector if you are sure your program does not create reference cycles. Automatic collection can be disabled by calling `gc.disable()`. To debug a leaking program call `gc.set_debug(gc.DEBUG_LEAK)`. Notice that this includes `gc.DEBUG_SAVEALL`, causing garbage-collected objects to be saved in `gc.garbage` for inspection.

The `gc` module provides the following functions:

`gc.enable()`

Enable automatic garbage collection.

`gc.disable()`

Disable automatic garbage collection.

`gc.isenabled()`

Returns true if automatic collection is enabled.

`gc.collect([generation])`

With no arguments, run a full collection. The optional argument *generation* may be an integer specifying which generation to collect (from 0 to 2). A `ValueError` is raised if the generation number is invalid. The number of unreachable objects found is returned. Changed in version 2.5: The optional *generation* argument was added. Changed in version 2.6: The free lists maintained for a number of built-in types are cleared whenever a full collection or collection of the highest generation (2) is run. Not all items in some free lists may be freed due to the particular implementation, in particular `int` and `float`.

`gc.set_debug(flags)`

Set the garbage collection debugging flags. Debugging information will be written to `sys.stderr`. See below for a list of debugging flags which can be combined using bit operations to control debugging.

`gc.get_debug()`

Return the debugging flags currently set.

`gc.get_objects()`

Returns a list of all objects tracked by the collector, excluding the list returned. New in version 2.2.

`gc.set_threshold(threshold0[, threshold1[, threshold2]])`

Set the garbage collection thresholds (the collection frequency). Setting *threshold0* to zero disables collection.

The GC classifies objects into three generations depending on how many collection sweeps they have survived. New objects are placed in the youngest generation (generation 0). If an object survives a collection it is moved into the next older generation. Since generation 2 is the oldest generation, objects in that generation remain there after a collection. In order to decide when to run, the collector keeps track of the number object allocations and deallocations since the last collection. When the number of allocations minus the number of deallocations exceeds *threshold0*, collection starts. Initially only generation 0 is examined. If generation 0 has been examined more than *threshold1* times since generation 1 has been examined, then generation 1 is examined as well. Similarly, *threshold2* controls the number of collections of generation 1 before collecting generation 2.

`gc.get_count()`

Return the current collection counts as a tuple of (`count0`, `count1`, `count2`). New in version 2.5.

`gc.get_threshold()`

Return the current collection thresholds as a tuple of (`threshold0`, `threshold1`, `threshold2`).

`gc.get_referrers(*objs)`

Return the list of objects that directly refer to any of `objs`. This function will only locate those containers which support garbage collection; extension types which do refer to other objects but do not support garbage collection will not be found.

Note that objects which have already been dereferenced, but which live in cycles and have not yet been collected by the garbage collector can be listed among the resulting referrers. To get only currently live objects, call `collect()` before calling `get_referrers()`.

Care must be taken when using objects returned by `get_referrers()` because some of them could still be under construction and hence in a temporarily invalid state. Avoid using `get_referrers()` for any purpose other than debugging. New in version 2.2.

### `gc.get_referents(*objs)`

Return a list of objects directly referred to by any of the arguments. The referents returned are those objects visited by the arguments' C-level `tp_traverse` methods (if any), and may not be all objects actually directly reachable. `tp_traverse` methods are supported only by objects that support garbage collection, and are only required to visit objects that may be involved in a cycle. So, for example, if an integer is directly reachable from an argument, that integer object may or may not appear in the result list. New in version 2.3.

### `gc.is_tracked(obj)`

Returns True if the object is currently tracked by the garbage collector, False otherwise. As a general rule, instances of atomic types aren't tracked and instances of non-atomic types (containers, user-defined objects...) are. However, some type-specific optimizations can be present in order to suppress the garbage collector footprint of simple instances (e.g. dicts containing only atomic keys and values):

```
>>> gc.is_tracked(0)
False
>>> gc.is_tracked("a")
False
>>> gc.is_tracked([])
True
>>> gc.is_tracked({})
False
>>> gc.is_tracked({"a": 1})
False
>>> gc.is_tracked({"a": []})
True
```

New in version 2.7.

The following variable is provided for read-only access (you can mutate its value but should not rebind it):

### `gc.garbage`

A list of objects which the collector found to be unreachable but could not be freed (uncollectable objects). By default, this list contains only objects with `__del__()` methods.<sup>2</sup> Objects that have `__del__()` methods and are part of a reference cycle cause the entire reference cycle to be uncollectable, including objects not necessarily in the cycle but reachable only from it. Python doesn't collect such cycles automatically because, in general, it isn't possible for Python to guess a safe order in which to run the `__del__()` methods. If you know a safe order, you can force the issue by examining the *garbage* list, and explicitly breaking cycles due to your objects within the list. Note that these objects are kept alive even so by virtue of being in the *garbage* list, so they should be removed from *garbage* too. For example, after breaking cycles, do `del gc.garbage[:]` to empty the list. It's generally better to avoid the issue by not creating cycles containing objects with `__del__()` methods, and *garbage* can be examined in that case to verify that no such cycles are being created.

If `DEBUG_SAVEALL` is set, then all unreachable objects will be added to this list rather than freed.

The following constants are provided for use with `set_debug()`:

### `gc.DEBUG_STATS`

Print statistics during collection. This information can be useful when tuning the collection frequency.

---

<sup>2</sup> Prior to Python 2.2, the list contained all instance objects in unreachable cycles, not only those with `__del__()` methods.

**gc.DEBUG\_COLLECTABLE**

Print information on collectable objects found.

**gc.DEBUG\_UNCOLLECTABLE**

Print information of uncollectable objects found (objects which are not reachable but cannot be freed by the collector). These objects will be added to the `garbage` list.

**gc.DEBUG\_INSTANCES**

When `DEBUG_COLLECTABLE` or `DEBUG_UNCOLLECTABLE` is set, print information about instance objects found.

**gc.DEBUG\_OBJECTS**

When `DEBUG_COLLECTABLE` or `DEBUG_UNCOLLECTABLE` is set, print information about objects other than instance objects found.

**gc.DEBUG\_SAVEALL**

When set, all unreachable objects found will be appended to `garbage` rather than being freed. This can be useful for debugging a leaking program.

**gc.DEBUG\_LEAK**

The debugging flags necessary for the collector to print information about a leaking program (equal to `DEBUG_COLLECTABLE | DEBUG_UNCOLLECTABLE | DEBUG_INSTANCES | DEBUG_OBJECTS | DEBUG_SAVEALL`).

## 27.13 inspect — Inspect live objects

New in version 2.1. **Source code:** [Lib/inspect.py](#)

The `inspect` module provides several useful functions to help get information about live objects such as modules, classes, methods, functions, tracebacks, frame objects, and code objects. For example, it can help you examine the contents of a class, retrieve the source code of a method, extract and format the argument list for a function, or get all the information you need to display a detailed traceback.

There are four main kinds of services provided by this module: type checking, getting source code, inspecting classes and functions, and examining the interpreter stack.

### 27.13.1 Types and members

The `getmembers()` function retrieves the members of an object such as a class or module. The sixteen functions whose names begin with “is” are mainly provided as convenient choices for the second argument to `getmembers()`. They also help you determine when you can expect to find the following special attributes:

Type	Attribute	Description
module	<code>__doc__</code>	documentation string
	<code>__file__</code>	filename (missing for built-in modules)
class	<code>__doc__</code>	documentation string
	<code>__module__</code>	name of module in which this class was defined
method	<code>__doc__</code>	documentation string
	<code>__name__</code>	name with which this method was defined
	<code>im_class</code>	class object that asked for this method
	<code>im_func</code> or <code>__func__</code>	function object containing implementation of method
	<code>im_self</code> or <code>__self__</code>	instance to which this method is bound, or <code>None</code>

Continued on

Table 27.1 – continued from previous page

function	<code>__doc__</code>	documentation string	
	<code>__name__</code>	name with which this function was defined	
	<code>func_code</code>	code object containing compiled function <i>bytecode</i>	
	<code>func_defaults</code>	tuple of any default values for arguments	
	<code>func_doc</code>	(same as <code>__doc__</code> )	
	<code>func_globals</code>	global namespace in which this function was defined	
	<code>func_name</code>	(same as <code>__name__</code> )	
	generator	<code>__iter__</code>	defined to support iteration over container
		<code>close</code>	raises new <code>GeneratorExit</code> exception inside the generator to terminate the iteration
		<code>gi_code</code>	code object
<code>gi_frame</code>		frame object or possibly <code>None</code> once the generator has been exhausted	
<code>gi_running</code>		set to 1 when generator is executing, 0 otherwise	
<code>next</code>		return the next item from the container	
traceback	<code>send</code>	resumes the generator and “sends” a value that becomes the result of the current yield-expression	
	<code>throw</code>	used to raise an exception inside the generator	
	<code>tb_frame</code>	frame object at this level	
frame	<code>tb_lasti</code>	index of last attempted instruction in bytecode	
	<code>tb_lineno</code>	current line number in Python source code	
	<code>tb_next</code>	next inner traceback object (called by this level)	
code	<code>f_back</code>	next outer frame object (this frame’s caller)	
	<code>f_builtins</code>	builtins namespace seen by this frame	
	<code>f_code</code>	code object being executed in this frame	
	<code>f_exc_traceback</code>	traceback if raised in this frame, or <code>None</code>	
	<code>f_exc_type</code>	exception type if raised in this frame, or <code>None</code>	
	<code>f_exc_value</code>	exception value if raised in this frame, or <code>None</code>	
	<code>f_globals</code>	global namespace seen by this frame	
	<code>f_lasti</code>	index of last attempted instruction in bytecode	
	<code>f_lineno</code>	current line number in Python source code	
	<code>f_locals</code>	local namespace seen by this frame	
	<code>f_restricted</code>	0 or 1 if frame is in restricted execution mode	
	<code>f_trace</code>	tracing function for this frame, or <code>None</code>	
	builtin	<code>co_argcount</code>	number of arguments (not including <code>*</code> or <code>**</code> args)
<code>co_code</code>		string of raw compiled bytecode	
<code>co_consts</code>		tuple of constants used in the bytecode	
<code>co_filename</code>		name of file in which this code object was created	
<code>co_firstlineno</code>		number of first line in Python source code	
<code>co_flags</code>		bitmap: 1=optimized   2=newlocals   4=*arg   8=**arg	
<code>co_lnotab</code>		encoded mapping of line numbers to bytecode indices	
<code>co_name</code>		name with which this code object was defined	
<code>co_names</code>		tuple of names of local variables	
<code>co_nlocals</code>		number of local variables	
<code>co_stacksize</code>		virtual machine stack space required	
<code>co_varnames</code>		tuple of names of arguments and local variables	
builtin		<code>__doc__</code>	documentation string
	<code>__name__</code>	original name of this function or method	
	<code>__self__</code>	instance to which a method is bound, or <code>None</code>	

Note:

1. Changed in version 2.2: `im_class` used to refer to the class that defined the method.

`inspect.getmembers(object[, predicate])`

Return all the members of an object in a list of (name, value) pairs sorted by name. If the optional *predicate*

argument is supplied, only members for which the predicate returns a true value are included.

---

**Note:** `getmembers()` does not return metaclass attributes when the argument is a class (this behavior is inherited from the `dir()` function).

---

`inspect.getmoduleinfo(path)`

Return a tuple of values that describe how Python will interpret the file identified by *path* if it is a module, or `None` if it would not be identified as a module. The return tuple is (*name*, *suffix*, *mode*, *module\_type*), where *name* is the name of the module without the name of any enclosing package, *suffix* is the trailing part of the file name (which may not be a dot-delimited extension), *mode* is the `open()` mode that would be used ('r' or 'rb'), and *module\_type* is an integer giving the type of the module. *module\_type* will have a value which can be compared to the constants defined in the `imp` module; see the documentation for that module for more information on module types. Changed in version 2.6: Returns a *named tuple* `ModuleInfo(name, suffix, mode, module_type)`.

`inspect.getmodulename(path)`

Return the name of the module named by the file *path*, without including the names of enclosing packages. This uses the same algorithm as the interpreter uses when searching for modules. If the name cannot be matched according to the interpreter's rules, `None` is returned.

`inspect.ismodule(object)`

Return true if the object is a module.

`inspect.isclass(object)`

Return true if the object is a class, whether built-in or created in Python code.

`inspect.ismethod(object)`

Return true if the object is a bound method written in Python.

`inspect.isfunction(object)`

Return true if the object is a Python function, which includes functions created by a *lambda* expression.

`inspect.isgeneratorfunction(object)`

Return true if the object is a Python generator function. New in version 2.6.

`inspect.isgenerator(object)`

Return true if the object is a generator. New in version 2.6.

`inspect.istraceback(object)`

Return true if the object is a traceback.

`inspect.isframe(object)`

Return true if the object is a frame.

`inspect.iscode(object)`

Return true if the object is a code.

`inspect.isbuiltin(object)`

Return true if the object is a built-in function or a bound built-in method.

`inspect.isroutine(object)`

Return true if the object is a user-defined or built-in function or method.

`inspect.isabstract(object)`

Return true if the object is an abstract base class. New in version 2.6.

`inspect.ismethoddescriptor(object)`

Return true if the object is a method descriptor, but not if `ismethod()`, `isclass()`, `isfunction()` or `isbuiltin()` are true.

This is new as of Python 2.2, and, for example, is true of `int.__add__`. An object passing this test has a `__get__` attribute but not a `__set__` attribute, but beyond that the set of attributes varies. `__name__` is usually sensible, and `__doc__` often is.

Methods implemented via descriptors that also pass one of the other tests return false from the `ismethoddescriptor()` test, simply because the other tests promise more – you can, e.g., count on having the `im_func` attribute (etc) when an object passes `ismethod()`.

`inspect.isdatadescriptor(object)`

Return true if the object is a data descriptor.

Data descriptors have both a `__get__` and a `__set__` attribute. Examples are properties (defined in Python), getsets, and members. The latter two are defined in C and there are more specific tests available for those types, which is robust across Python implementations. Typically, data descriptors will also have `__name__` and `__doc__` attributes (properties, getsets, and members have both of these attributes), but this is not guaranteed. New in version 2.3.

`inspect.isgetsetdescriptor(object)`

Return true if the object is a getset descriptor.

**CPython implementation detail:** getsets are attributes defined in extension modules via `PyGetSetDef` structures. For Python implementations without such types, this method will always return `False`. New in version 2.5.

`inspect.ismemberdescriptor(object)`

Return true if the object is a member descriptor.

**CPython implementation detail:** Member descriptors are attributes defined in extension modules via `PyMemberDef` structures. For Python implementations without such types, this method will always return `False`. New in version 2.5.

### 27.13.2 Retrieving source code

`inspect.getdoc(object)`

Get the documentation string for an object, cleaned up with `cleandoc()`.

`inspect.getcomments(object)`

Return in a single string any lines of comments immediately preceding the object's source code (for a class, function, or method), or at the top of the Python source file (if the object is a module).

`inspect.getfile(object)`

Return the name of the (text or binary) file in which an object was defined. This will fail with a `TypeError` if the object is a built-in module, class, or function.

`inspect.getmodule(object)`

Try to guess which module an object was defined in.

`inspect.getsourcefile(object)`

Return the name of the Python source file in which an object was defined. This will fail with a `TypeError` if the object is a built-in module, class, or function.

`inspect.getsourcelines(object)`

Return a list of source lines and starting line number for an object. The argument may be a module, class, method, function, traceback, frame, or code object. The source code is returned as a list of the lines corresponding to the object and the line number indicates where in the original source file the first line of code was found. An `IOError` is raised if the source code cannot be retrieved.

`inspect.getsource(object)`

Return the text of the source code for an object. The argument may be a module, class, method, function,

traceback, frame, or code object. The source code is returned as a single string. An `IOError` is raised if the source code cannot be retrieved.

`inspect.cleandoc(doc)`

Clean up indentation from docstrings that are indented to line up with blocks of code. Any whitespace that can be uniformly removed from the second line onwards is removed. Also, all tabs are expanded to spaces. New in version 2.6.

### 27.13.3 Classes and functions

`inspect.getclasstree(classes[, unique])`

Arrange the given list of classes into a hierarchy of nested lists. Where a nested list appears, it contains classes derived from the class whose entry immediately precedes the list. Each entry is a 2-tuple containing a class and a tuple of its base classes. If the *unique* argument is true, exactly one entry appears in the returned structure for each class in the given list. Otherwise, classes using multiple inheritance and their descendants will appear multiple times.

`inspect.getargspec(func)`

Get the names and default values of a Python function's arguments. A tuple of four things is returned: (*args*, *varargs*, *keywords*, *defaults*). *args* is a list of the argument names (it may contain nested lists). *varargs* and *keywords* are the names of the \* and \*\* arguments or None. *defaults* is a tuple of default argument values or None if there are no default arguments; if this tuple has *n* elements, they correspond to the last *n* elements listed in *args*. Changed in version 2.6: Returns a *named tuple* `ArgSpec(args, varargs, keywords, defaults)`.

`inspect.getargvalues(frame)`

Get information about arguments passed into a particular frame. A tuple of four things is returned: (*args*, *varargs*, *keywords*, *locals*). *args* is a list of the argument names (it may contain nested lists). *varargs* and *keywords* are the names of the \* and \*\* arguments or None. *locals* is the locals dictionary of the given frame. Changed in version 2.6: Returns a *named tuple* `ArgInfo(args, varargs, keywords, locals)`.

`inspect.formatargspec(args[, varargs, varkw, defaults, formatarg, formatvarargs, formatvarkw, formatvalue, join])`

Format a pretty argument spec from the four values returned by `getargspec()`. The *format\** arguments are the corresponding optional formatting functions that are called to turn names and values into strings.

`inspect.formatargvalues(args[, varargs, varkw, locals, formatarg, formatvarargs, formatvarkw, formatvalue, join])`

Format a pretty argument spec from the four values returned by `getargvalues()`. The *format\** arguments are the corresponding optional formatting functions that are called to turn names and values into strings.

`inspect.getmro(cls)`

Return a tuple of class *cls*'s base classes, including *cls*, in method resolution order. No class appears more than once in this tuple. Note that the method resolution order depends on *cls*'s type. Unless a very peculiar user-defined metatype is in use, *cls* will be the first element of the tuple.

`inspect.getcallargs(func[, *args][, **kws])`

Bind the *args* and *kws* to the argument names of the Python function or method *func*, as if it was called with them. For bound methods, bind also the first argument (typically named *self*) to the associated instance. A dict is returned, mapping the argument names (including the names of the \* and \*\* arguments, if any) to their values from *args* and *kws*. In case of invoking *func* incorrectly, i.e. whenever `func(*args, **kws)` would raise an exception because of incompatible signature, an exception of the same type and the same or similar message is raised. For example:

```
>>> from inspect import getcallargs
>>> def f(a, b=1, *pos, **named):
```

```
...     pass
>>> getcallargs(f, 1, 2, 3)
{'a': 1, 'named': {}, 'b': 2, 'pos': (3,)}
>>> getcallargs(f, a=2, x=4)
{'a': 2, 'named': {'x': 4}, 'b': 1, 'pos': ()}
>>> getcallargs(f)
Traceback (most recent call last):
...
TypeError: f() takes at least 1 argument (0 given)
```

New in version 2.7.

### 27.13.4 The interpreter stack

When the following functions return “frame records,” each record is a tuple of six items: the frame object, the filename, the line number of the current line, the function name, a list of lines of context from the source code, and the index of the current line within that list.

---

**Note:** Keeping references to frame objects, as found in the first element of the frame records these functions return, can cause your program to create reference cycles. Once a reference cycle has been created, the lifespan of all objects which can be accessed from the objects which form the cycle can become much longer even if Python’s optional cycle detector is enabled. If such cycles must be created, it is important to ensure they are explicitly broken to avoid the delayed destruction of objects and increased memory consumption which occurs.

Though the cycle detector will catch these, destruction of the frames (and local variables) can be made deterministic by removing the cycle in a `finally` clause. This is also important if the cycle detector was disabled when Python was compiled or using `gc.disable()`. For example:

```
def handle_stackframe_without_leak():
    frame = inspect.currentframe()
    try:
        # do something with the frame
    finally:
        del frame
```

---

The optional *context* argument supported by most of these functions specifies the number of lines of context to return, which are centered around the current line.

`inspect.getframeinfo` (*frame*[, *context*])

Get information about a frame or traceback object. A 5-tuple is returned, the last five elements of the frame’s frame record. Changed in version 2.6: Returns a *named tuple* `Traceback(filename, lineno, function, code_context, index)`.

`inspect.getouterframes` (*frame*[, *context*])

Get a list of frame records for a frame and all outer frames. These frames represent the calls that lead to the creation of *frame*. The first entry in the returned list represents *frame*; the last entry represents the outermost call on *frame*’s stack.

`inspect.getinnerframes` (*traceback*[, *context*])

Get a list of frame records for a traceback’s frame and all inner frames. These frames represent calls made as a consequence of *frame*. The first entry in the list represents *traceback*; the last entry represents where the exception was raised.

`inspect.currentframe` ()

Return the frame object for the caller’s stack frame.

**CPython implementation detail:** This function relies on Python stack frame support in the interpreter, which isn't guaranteed to exist in all implementations of Python. If running in an implementation without Python stack frame support this function returns `None`.

```
inspect.stack([context])
```

Return a list of frame records for the caller's stack. The first entry in the returned list represents the caller; the last entry represents the outermost call on the stack.

```
inspect.trace([context])
```

Return a list of frame records for the stack between the current frame and the frame in which an exception currently being handled was raised in. The first entry in the list represents the caller; the last entry represents where the exception was raised.

## 27.14 `site` — Site-specific configuration hook

**Source code:** [Lib/site.py](#)

**This module is automatically imported during initialization.** The automatic import can be suppressed using the interpreter's `-S` option.

Importing this module will append site-specific paths to the module search path and add a few builtins.

It starts by constructing up to four directories from a head and a tail part. For the head part, it uses `sys.prefix` and `sys.exec_prefix`; empty heads are skipped. For the tail part, it uses the empty string and then `lib/site-packages` (on Windows) or `lib/pythonX.Y/site-packages` and then `lib/site-python` (on Unix and Macintosh). For each of the distinct head-tail combinations, it sees if it refers to an existing directory, and if so, adds it to `sys.path` and also inspects the newly added path for configuration files.

A path configuration file is a file whose name has the form `name.pth` and exists in one of the four directories mentioned above; its contents are additional items (one per line) to be added to `sys.path`. Non-existing items are never added to `sys.path`, and no check is made that the item refers to a directory rather than a file. No item is added to `sys.path` more than once. Blank lines and lines beginning with `#` are skipped. Lines starting with `import` (followed by space or tab) are executed. Changed in version 2.6: A space or tab is now required after the import keyword. For example, suppose `sys.prefix` and `sys.exec_prefix` are set to `/usr/local`. The Python X.Y library is then installed in `/usr/local/lib/pythonX.Y`. Suppose this has a subdirectory `/usr/local/lib/pythonX.Y/site-packages` with three subsubdirectories, `foo`, `bar` and `spam`, and two path configuration files, `foo.pth` and `bar.pth`. Assume `foo.pth` contains the following:

```
# foo package configuration

foo
bar
bletch
```

and `bar.pth` contains:

```
# bar package configuration

bar
```

Then the following version-specific directories are added to `sys.path`, in this order:

```
/usr/local/lib/pythonX.Y/site-packages/bar
/usr/local/lib/pythonX.Y/site-packages/foo
```

Note that `bletch` is omitted because it doesn't exist; the `bar` directory precedes the `foo` directory because `bar.pth` comes alphabetically before `foo.pth`; and `spam` is omitted because it is not mentioned in either path configuration file.

After these path manipulations, an attempt is made to import a module named `sitecustomize`, which can perform arbitrary site-specific customizations. It is typically created by a system administrator in the `site-packages` directory. If this import fails with an `ImportError` exception, it is silently ignored.

After this, an attempt is made to import a module named `usercustomize`, which can perform arbitrary user-specific customizations, if `ENABLE_USER_SITE` is true. This file is intended to be created in the user `site-packages` directory (see below), which is part of `sys.path` unless disabled by `-s`. An `ImportError` will be silently ignored.

Note that for some non-Unix systems, `sys.prefix` and `sys.exec_prefix` are empty, and the path manipulations are skipped; however the import of `sitecustomize` and `usercustomize` is still attempted.

### `site.PREFIXES`

A list of prefixes for `site-packages` directories. New in version 2.6.

### `site.ENABLE_USER_SITE`

Flag showing the status of the user `site-packages` directory. True means that it is enabled and was added to `sys.path`. False means that it was disabled by user request (with `-s` or

`PYTHONNOUSERSITE`). None means it was disabled for security reasons (mismatch between user or group id and effective id) or by an administrator. New in version 2.6.

### `site.USER_SITE`

Path to the user `site-packages` for the running Python. Can be None if `getusersitepackages()` hasn't been called yet. Default value is `~/local/lib/pythonX.Y/site-packages` for UNIX and non-framework Mac OS X builds, `~/Library/Python/X.Y/lib/python/site-packages` for Mac framework builds, and `%APPDATA%\Python\PythonXY\site-packages` on Windows. This directory is a `site` directory, which means that `.pth` files in it will be processed. New in version 2.6.

### `site.USER_BASE`

Path to the base directory for the user `site-packages`. Can be None if `getuserbase()` hasn't been called yet. Default value is `~/local` for UNIX and Mac OS X non-framework builds, `~/Library/Python/X.Y` for Mac framework builds, and `%APPDATA%\Python` for Windows. This value is used by Distutils to compute the installation directories for scripts, data files, Python modules, etc. for the *user installation scheme*. See also `PYTHONUSERBASE`. New in version 2.6.

### `site.addsitedir(sitedir, known_paths=None)`

Add a directory to `sys.path` and process its `.pth` files. Typically used in `sitecustomize` or `usercustomize` (see above).

### `site.getsitepackages()`

Return a list containing all global `site-packages` directories (and possibly `site-python`). New in version 2.7.

### `site.getuserbase()`

Return the path of the user base directory, `USER_BASE`. If it is not initialized yet, this function will also set it, respecting

`PYTHONUSERBASE`. New in version 2.7.

### `site.getusersitepackages()`

Return the path of the user-specific `site-packages` directory, `USER_SITE`. If it is not initialized yet, this function will also set it, respecting `PYTHONNOUSERSITE` and `USER_BASE`. New in version 2.7.

The `site` module also provides a way to get the user directories from the command line:

```
$ python3 -m site --user-site
/home/user/.local/lib/python3.3/site-packages
```

If it is called without arguments, it will print the contents of `sys.path` on the standard output, followed by the value of `USER_BASE` and whether the directory exists, then the same thing for `USER_SITE`, and finally the value of `ENABLE_USER_SITE`.

**-user-base**

Print the path to the user base directory.

**-user-site**

Print the path to the user site-packages directory.

If both options are given, user base and user site will be printed (always in this order), separated by `os.pathsep`.

If any option is given, the script will exit with one of these values: 0 if the user site-packages directory is enabled, 1 if it was disabled by the user, 2 if it is disabled for security reasons or by an administrator, and a value greater than 2 if there is an error.

**See Also:**

**PEP 370** – Per user site-packages directory

## 27.15 user — User-specific configuration hook

Deprecated since version 2.6: The `user` module has been removed in Python 3. As a policy, Python doesn't run user-specified code on startup of Python programs. (Only interactive sessions execute the script specified in the `PYTHONSTARTUP` environment variable if it exists).

However, some programs or sites may find it convenient to allow users to have a standard customization file, which gets run when a program requests it. This module implements such a mechanism. A program that wishes to use the mechanism must execute the statement

```
import user
```

The `user` module looks for a file `.pythonrc.py` in the user's home directory and if it can be opened, executes it (using `execfile()`) in its own (the module `user`'s) global namespace. Errors during this phase are not caught; that's up to the program that imports the `user` module, if it wishes. The home directory is assumed to be named by the `HOME` environment variable; if this is not set, the current directory is used.

The user's `.pythonrc.py` could conceivably test for `sys.version` if it wishes to do different things depending on the Python version.

A warning to users: be very conservative in what you place in your `.pythonrc.py` file. Since you don't know which programs will use it, changing the behavior of standard modules or functions is generally not a good idea.

A suggestion for programmers who wish to use this mechanism: a simple way to let users specify options for your package is to have them define variables in their `.pythonrc.py` file that you test in your module. For example, a module `spam` that has a verbosity level can look for a variable `user.spam_verbosity`, as follows:

```
import user
```

```
verbosity = bool(getattr(user, "spam_verbosity", 0))
```

(The three-argument form of `getattr()` is used in case the user has not defined `spam_verbosity` in their `.pythonrc.py` file.)

Programs with extensive customization needs are better off reading a program-specific customization file.

Programs with security or privacy concerns should *not* import this module; a user can easily break into a program by placing arbitrary code in the `.pythonrc.py` file.

Modules for general use should *not* import this module; it may interfere with the operation of the importing program.

See Also:

Module `site` Site-wide customization mechanism.

## 27.16 `fpectl` — Floating point exception control

Platforms: Unix

---

**Note:** The `fpectl` module is not built by default, and its usage is discouraged and may be dangerous except in the hands of experts. See also the section *Limitations and other considerations* on limitations for more details.

---

Most computers carry out floating point operations in conformance with the so-called IEEE-754 standard. On any real computer, some floating point operations produce results that cannot be expressed as a normal floating point value. For example, try

```
>>> import math
>>> math.exp(1000)
inf
>>> math.exp(1000) / math.exp(1000)
nan
```

(The example above will work on many platforms. DEC Alpha may be one exception.) “Inf” is a special, non-numeric value in IEEE-754 that stands for “infinity”, and “nan” means “not a number.” Note that, other than the non-numeric results, nothing special happened when you asked Python to carry out those calculations. That is in fact the default behaviour prescribed in the IEEE-754 standard, and if it works for you, stop reading now.

In some circumstances, it would be better to raise an exception and stop processing at the point where the faulty operation was attempted. The `fpectl` module is for use in that situation. It provides control over floating point units from several hardware manufacturers, allowing the user to turn on the generation of SIGFPE whenever any of the IEEE-754 exceptions Division by Zero, Overflow, or Invalid Operation occurs. In tandem with a pair of wrapper macros that are inserted into the C code comprising your python system, SIGFPE is trapped and converted into the Python `FloatingPointError` exception.

The `fpectl` module defines the following functions and may raise the given exception:

`fpectl.turnon_sigfpe()`  
Turn on the generation of SIGFPE, and set up an appropriate signal handler.

`fpectl.turnoff_sigfpe()`  
Reset default handling of floating point exceptions.

**exception `fpectl.FloatingPointError`**

After `turnon_sigfpe()` has been executed, a floating point operation that raises one of the IEEE-754 exceptions Division by Zero, Overflow, or Invalid operation will in turn raise this standard Python exception.

### 27.16.1 Example

The following example demonstrates how to start up and test operation of the `fpectl` module.

```
>>> import fpectl
>>> import fpetest
>>> fpectl.turnon_sigfpe()
>>> fpetest.test()
overflow          PASS
FloatingPointError: Overflow
```

```

div by 0          PASS
FloatingPointError: Division by zero
  [ more output from test elided ]
>>> import math
>>> math.exp(1000)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
FloatingPointError: in math_1

```

## 27.16.2 Limitations and other considerations

Setting up a given processor to trap IEEE-754 floating point errors currently requires custom code on a per-architecture basis. You may have to modify `fpectl` to control your particular hardware.

Conversion of an IEEE-754 exception to a Python exception requires that the wrapper macros `PyFPE_START_PROTECT` and `PyFPE_END_PROTECT` be inserted into your code in an appropriate fashion. Python itself has been modified to support the `fpectl` module, but many other codes of interest to numerical analysts have not.

The `fpectl` module is not thread-safe.

### See Also:

Some files in the source distribution may be interesting in learning more about how this module operates. The include file `Include/pyfpe.h` discusses the implementation of this module at some length. `Modules/fpetestmodule.c` gives several examples of use. Many additional examples can be found in `Objects/floatobject.c`.

## 27.17 `distutils` — Building and installing Python modules

The `distutils` package provides support for building and installing additional modules into a Python installation. The new modules may be either 100%-pure Python, or may be extension modules written in C, or may be collections of Python packages which include modules coded in both Python and C.

This package is discussed in two separate chapters:

### See Also:

***distutils-index*** The manual for developers and packagers of Python modules. This describes how to prepare `distutils`-based packages so that they may be easily installed into an existing Python installation.

***install-index*** An “administrators” manual which includes information on installing modules into an existing Python installation. You do not need to be a Python programmer to read this manual.



# CUSTOM PYTHON INTERPRETERS

The modules described in this chapter allow writing interfaces similar to Python's interactive interpreter. If you want a Python interpreter that supports some special feature in addition to the Python language, you should look at the `code` module. (The `codeop` module is lower-level, used to support compiling a possibly-incomplete chunk of Python code.)

The full list of modules described in this chapter is:

## 28.1 `code` — Interpreter base classes

The `code` module provides facilities to implement read-eval-print loops in Python. Two classes and convenience functions are included which can be used to build applications which provide an interactive interpreter prompt.

**class** `code.InteractiveInterpreter` (`[locals]`)

This class deals with parsing and interpreter state (the user's namespace); it does not deal with input buffering or prompting or input file naming (the filename is always passed in explicitly). The optional `locals` argument specifies the dictionary in which code will be executed; it defaults to a newly created dictionary with key `'__name__'` set to `'__console__'` and key `'__doc__'` set to `None`.

**class** `code.InteractiveConsole` (`[locals[, filename]]`)

Closely emulate the behavior of the interactive Python interpreter. This class builds on `InteractiveInterpreter` and adds prompting using the familiar `sys.ps1` and `sys.ps2`, and input buffering.

`code.interact` (`[banner[, readfunc[, local]]]`)

Convenience function to run a read-eval-print loop. This creates a new instance of `InteractiveConsole` and sets `readfunc` to be used as the `raw_input()` method, if provided. If `local` is provided, it is passed to the `InteractiveConsole` constructor for use as the default namespace for the interpreter loop. The `interact()` method of the instance is then run with `banner` passed as the banner to use, if provided. The console object is discarded after use.

`code.compile_command` (`source[, filename[, symbol]]`)

This function is useful for programs that want to emulate Python's interpreter main loop (a.k.a. the read-eval-print loop). The tricky part is to determine when the user has entered an incomplete command that can be completed by entering more text (as opposed to a complete command or a syntax error). This function *almost* always makes the same decision as the real interpreter main loop.

`source` is the source string; `filename` is the optional filename from which source was read, defaulting to `'<input>'`; and `symbol` is the optional grammar start symbol, which should be either `'single'` (the default) or `'eval'`.

Returns a code object (the same as `compile(source, filename, symbol)`) if the command is complete and valid; `None` if the command is incomplete; raises `SyntaxError` if the command is complete and

contains a syntax error, or raises `OverflowError` or `ValueError` if the command contains an invalid literal.

### 28.1.1 Interactive Interpreter Objects

`InteractiveInterpreter.runsource` (*source* [, *filename* [, *symbol* ]])

Compile and run some source in the interpreter. Arguments are the same as for `compile_command()`; the default for *filename* is '`<input>`', and for *symbol* is '`single`'. One several things can happen:

- The input is incorrect; `compile_command()` raised an exception (`SyntaxError` or `OverflowError`). A syntax traceback will be printed by calling the `showsyntaxerror()` method. `runsource()` returns `False`.
- The input is incomplete, and more input is required; `compile_command()` returned `None`. `runsource()` returns `True`.
- The input is complete; `compile_command()` returned a code object. The code is executed by calling the `runcode()` (which also handles run-time exceptions, except for `SystemExit`). `runsource()` returns `False`.

The return value can be used to decide whether to use `sys.ps1` or `sys.ps2` to prompt the next line.

`InteractiveInterpreter.runcode` (*code*)

Execute a code object. When an exception occurs, `showtraceback()` is called to display a traceback. All exceptions are caught except `SystemExit`, which is allowed to propagate.

A note about `KeyboardInterrupt`: this exception may occur elsewhere in this code, and may not always be caught. The caller should be prepared to deal with it.

`InteractiveInterpreter.showsyntaxerror` ([*filename*])

Display the syntax error that just occurred. This does not display a stack trace because there isn't one for syntax errors. If *filename* is given, it is stuffed into the exception instead of the default filename provided by Python's parser, because it always uses '`<string>`' when reading from a string. The output is written by the `write()` method.

`InteractiveInterpreter.showtraceback` ()

Display the exception that just occurred. We remove the first stack item because it is within the interpreter object implementation. The output is written by the `write()` method.

`InteractiveInterpreter.write` (*data*)

Write a string to the standard error stream (`sys.stderr`). Derived classes should override this to provide the appropriate output handling as needed.

### 28.1.2 Interactive Console Objects

The `InteractiveConsole` class is a subclass of `InteractiveInterpreter`, and so offers all the methods of the interpreter objects as well as the following additions.

`InteractiveConsole.interact` ([*banner*])

Closely emulate the interactive Python console. The optional banner argument specify the banner to print before the first interaction; by default it prints a banner similar to the one printed by the standard Python interpreter, followed by the class name of the console object in parentheses (so as not to confuse this with the real interpreter – since it's so close!).

`InteractiveConsole.push` (*line*)

Push a line of source text to the interpreter. The line should not have a trailing newline; it may have internal newlines. The line is appended to a buffer and the interpreter's `runsource()` method is called with the

concatenated contents of the buffer as source. If this indicates that the command was executed or invalid, the buffer is reset; otherwise, the command is incomplete, and the buffer is left as it was after the line was appended. The return value is `True` if more input is required, `False` if the line was dealt with in some way (this is the same as `runsource()`).

`InteractiveConsole.resetbuffer()`

Remove any unhandled source text from the input buffer.

`InteractiveConsole.raw_input([prompt])`

Write a prompt and read a line. The returned line does not include the trailing newline. When the user enters the EOF key sequence, `EOFError` is raised. The base implementation uses the built-in function `raw_input()`; a subclass may replace this with a different implementation.

## 28.2 codeop — Compile Python code

The `codeop` module provides utilities upon which the Python read-eval-print loop can be emulated, as is done in the `code` module. As a result, you probably don't want to use the module directly; if you want to include such a loop in your program you probably want to use the `code` module instead.

There are two parts to this job:

1. Being able to tell if a line of input completes a Python statement: in short, telling whether to print '>>>' or '...' next.
2. Remembering which future statements the user has entered, so subsequent input can be compiled with these in effect.

The `codeop` module provides a way of doing each of these things, and a way of doing them both.

To do just the former:

`codeop.compile_command(source[, filename[, symbol]])`

Tries to compile *source*, which should be a string of Python code and return a code object if *source* is valid Python code. In that case, the filename attribute of the code object will be *filename*, which defaults to '<input>'. Returns `None` if *source* is *not* valid Python code, but is a prefix of valid Python code.

If there is a problem with *source*, an exception will be raised. `SyntaxError` is raised if there is invalid Python syntax, and `OverflowError` or `ValueError` if there is an invalid literal.

The *symbol* argument determines whether *source* is compiled as a statement ('single', the default) or as an *expression* ('eval'). Any other value will cause `ValueError` to be raised.

---

**Note:** It is possible (but not likely) that the parser stops parsing with a successful outcome before reaching the end of the source; in this case, trailing symbols may be ignored instead of causing an error. For example, a backslash followed by two newlines may be followed by arbitrary garbage. This will be fixed once the API for the parser is better.

---

**class** `codeop.Compile`

Instances of this class have `__call__()` methods identical in signature to the built-in function `compile()`, but with the difference that if the instance compiles program text containing a `__future__` statement, the instance 'remembers' and compiles all subsequent program texts with the statement in force.

**class** `codeop.CommandCompiler`

Instances of this class have `__call__()` methods identical in signature to `compile_command()`; the difference is that if the instance compiles program text containing a `__future__` statement, the instance 'remembers' and compiles all subsequent program texts with the statement in force.

A note on version compatibility: the `Compile` and `CommandCompiler` are new in Python 2.2. If you want to enable the future-tracking features of 2.2 but also retain compatibility with 2.1 and earlier versions of Python you can either write

```
try:
    from codeop import CommandCompiler
    compile_command = CommandCompiler()
    del CommandCompiler
except ImportError:
    from codeop import compile_command
```

which is a low-impact change, but introduces possibly unwanted global state into your program, or you can write:

```
try:
    from codeop import CommandCompiler
except ImportError:
    def CommandCompiler():
        from codeop import compile_command
        return compile_command
```

and then call `CommandCompiler` every time you need a fresh compiler object.

# RESTRICTED EXECUTION

**Warning:** In Python 2.3 these modules have been disabled due to various known and not readily fixable security holes. The modules are still documented here to help in reading old code that uses the `rexec` and `Bastion` modules.

*Restricted execution* is the basic framework in Python that allows for the segregation of trusted and untrusted code. The framework is based on the notion that trusted Python code (a *supervisor*) can create a “padded cell” (or environment) with limited permissions, and run the untrusted code within this cell. The untrusted code cannot break out of its cell, and can only interact with sensitive system resources through interfaces defined and managed by the trusted code. The term “restricted execution” is favored over “safe-Python” since true safety is hard to define, and is determined by the way the restricted environment is created. Note that the restricted environments can be nested, with inner cells creating subcells of lesser, but never greater, privilege.

An interesting aspect of Python’s restricted execution model is that the interfaces presented to untrusted code usually have the same names as those presented to trusted code. Therefore no special interfaces need to be learned to write code designed to run in a restricted environment. And because the exact nature of the padded cell is determined by the supervisor, different restrictions can be imposed, depending on the application. For example, it might be deemed “safe” for untrusted code to read any file within a specified directory, but never to write a file. In this case, the supervisor may redefine the built-in `open()` function so that it raises an exception whenever the *mode* parameter is `'w'`. It might also perform a `chroot()`-like operation on the *filename* parameter, such that root is always relative to some safe “sandbox” area of the filesystem. In this case, the untrusted code would still see an built-in `open()` function in its environment, with the same calling interface. The semantics would be identical too, with `IOErrors` being raised when the supervisor determined that an unallowable parameter is being used.

The Python run-time determines whether a particular code block is executing in restricted execution mode based on the identity of the `__builtins__` object in its global variables: if this is (the dictionary of) the standard `__builtin__` module, the code is deemed to be unrestricted, else it is deemed to be restricted.

Python code executing in restricted mode faces a number of limitations that are designed to prevent it from escaping from the padded cell. For instance, the function object attribute `func_globals` and the class and instance object attribute `__dict__` are unavailable.

Two modules provide the framework for setting up restricted execution environments:

## 29.1 `rexec` — Restricted execution framework

Deprecated since version 2.6: The `rexec` module has been removed in Python 3.Changed in version 2.3: Disabled module.

**Warning:** The documentation has been left in place to help in reading old code that uses the module.

This module contains the `RExec` class, which supports `r_eval()`, `r_execfile()`, `r_exec()`, and `r_import()` methods, which are restricted versions of the standard Python functions `eval()`, `execfile()` and the `exec` and `import` statements. Code executed in this restricted environment will only have access to modules and functions that are deemed safe; you can subclass `RExec` to add or remove capabilities as desired.

**Warning:** While the `rexec` module is designed to perform as described below, it does have a few known vulnerabilities which could be exploited by carefully written code. Thus it should not be relied upon in situations requiring “production ready” security. In such situations, execution via sub-processes or very careful “cleansing” of both code and data to be processed may be necessary. Alternatively, help in patching known `rexec` vulnerabilities would be welcomed.

**Note:** The `RExec` class can prevent code from performing unsafe operations like reading or writing disk files, or using TCP/IP sockets. However, it does not protect against code using extremely large amounts of memory or processor time.

---

**class** `rexec.RExec` (`[hooks[, verbose]]`)

Returns an instance of the `RExec` class.

`hooks` is an instance of the `RHooks` class or a subclass of it. If it is omitted or `None`, the default `RHooks` class is instantiated. Whenever the `rexec` module searches for a module (even a built-in one) or reads a module’s code, it doesn’t actually go out to the file system itself. Rather, it calls methods of an `RHooks` instance that was passed to or created by its constructor. (Actually, the `RExec` object doesn’t make these calls — they are made by a module loader object that’s part of the `RExec` object. This allows another level of flexibility, which can be useful when changing the mechanics of `import` within the restricted environment.)

By providing an alternate `RHooks` object, we can control the file system accesses made to import a module, without changing the actual algorithm that controls the order in which those accesses are made. For instance, we could substitute an `RHooks` object that passes all filesystem requests to a file server elsewhere, via some RPC mechanism such as ILU. Grail’s applet loader uses this to support importing applets from a URL for a directory.

If `verbose` is true, additional debugging output may be sent to standard output.

It is important to be aware that code running in a restricted environment can still call the `sys.exit()` function. To disallow restricted code from exiting the interpreter, always protect calls that cause restricted code to run with a `try/except` statement that catches the `SystemExit` exception. Removing the `sys.exit()` function from the restricted environment is not sufficient — the restricted code could still use `raise SystemExit`. Removing `SystemExit` is not a reasonable option; some library code makes use of this and would break were it not available.

**See Also:**

**Grail Home Page** Grail is a Web browser written entirely in Python. It uses the `rexec` module as a foundation for supporting Python applets, and can be used as an example usage of this module.

### 29.1.1 RExec Objects

`RExec` instances support the following methods:

`RExec.r_eval` (`code`)

`code` must either be a string containing a Python expression, or a compiled code object, which will be evaluated in the restricted environment’s `__main__` module. The value of the expression or code object will be returned.

`RExec.r_exec` (`code`)

`code` must either be a string containing one or more lines of Python code, or a compiled code object, which will be executed in the restricted environment’s `__main__` module.

`RExec.r_execfile(filename)`

Execute the Python code contained in the file *filename* in the restricted environment's `__main__` module.

Methods whose names begin with `s_` are similar to the functions beginning with `r_`, but the code will be granted access to restricted versions of the standard I/O streams `sys.stdin`, `sys.stderr`, and `sys.stdout`.

`RExec.s_eval(code)`

*code* must be a string containing a Python expression, which will be evaluated in the restricted environment.

`RExec.s_exec(code)`

*code* must be a string containing one or more lines of Python code, which will be executed in the restricted environment.

`RExec.s_execfile(filename)`

Execute the Python code contained in the file *filename* in the restricted environment.

`RExec` objects must also support various methods which will be implicitly called by code executing in the restricted environment. Overriding these methods in a subclass is used to change the policies enforced by a restricted environment.

`RExec.r_import(modulename[, globals[, locals[, fromlist]])]`

Import the module *modulename*, raising an `ImportError` exception if the module is considered unsafe.

`RExec.r_open(filename[, mode[, bufsize]])]`

Method called when `open()` is called in the restricted environment. The arguments are identical to those of `open()`, and a file object (or a class instance compatible with file objects) should be returned. `RExec`'s default behaviour is allow opening any file for reading, but forbidding any attempt to write a file. See the example below for an implementation of a less restrictive `r_open()`.

`RExec.r_reload(module)`

Reload the module object *module*, re-parsing and re-initializing it.

`RExec.r_unload(module)`

Unload the module object *module* (remove it from the restricted environment's `sys.modules` dictionary).

And their equivalents with access to restricted standard I/O streams:

`RExec.s_import(modulename[, globals[, locals[, fromlist]])]`

Import the module *modulename*, raising an `ImportError` exception if the module is considered unsafe.

`RExec.s_reload(module)`

Reload the module object *module*, re-parsing and re-initializing it.

`RExec.s_unload(module)`

Unload the module object *module*.

## 29.1.2 Defining restricted environments

The `RExec` class has the following class attributes, which are used by the `__init__()` method. Changing them on an existing instance won't have any effect; instead, create a subclass of `RExec` and assign them new values in the class definition. Instances of the new class will then use those new values. All these attributes are tuples of strings.

`RExec.nok_builtin_names`

Contains the names of built-in functions which will *not* be available to programs running in the restricted environment. The value for `RExec` is `('open', 'reload', '__import__')`. (This gives the exceptions, because by far the majority of built-in functions are harmless. A subclass that wants to override this variable should probably start with the value from the base class and concatenate additional forbidden functions — when new dangerous built-in functions are added to Python, they will also be added to this module.)

**RExec.ok\_builtin\_modules**

Contains the names of built-in modules which can be safely imported. The value for `RExec` is ('audioop', 'array', 'binascii', 'cmath', 'errno', 'imageop', 'marshal', 'math', 'md5', 'operator', 'parser', 'regex', 'select', 'sha', '\_sre', 'strop', 'struct', 'time'). A similar remark about overriding this variable applies — use the value from the base class as a starting point.

**RExec.ok\_path**

Contains the directories which will be searched when an `import` is performed in the restricted environment. The value for `RExec` is the same as `sys.path` (at the time the module is loaded) for unrestricted code.

**RExec.ok\_posix\_names**

Contains the names of the functions in the `os` module which will be available to programs running in the restricted environment. The value for `RExec` is ('error', 'fstat', 'listdir', 'lstat', 'readlink', 'stat', 'times', 'uname', 'getpid', 'getppid', 'getcwd', 'getuid', 'getgid', 'geteuid', 'getegid').

**RExec.ok\_sys\_names**

Contains the names of the functions and variables in the `sys` module which will be available to programs running in the restricted environment. The value for `RExec` is ('ps1', 'ps2', 'copyright', 'version', 'platform', 'exit', 'maxint').

**RExec.ok\_file\_types**

Contains the file types from which modules are allowed to be loaded. Each file type is an integer constant defined in the `imp` module. The meaningful values are `PY_SOURCE`, `PY_COMPILED`, and `C_EXTENSION`. The value for `RExec` is (`C_EXTENSION`, `PY_SOURCE`). Adding `PY_COMPILED` in subclasses is not recommended; an attacker could exit the restricted execution mode by putting a forged byte-compiled file (`.pyc`) anywhere in your file system, for example by writing it to `/tmp` or uploading it to the `/incoming` directory of your public FTP server.

## 29.1.3 An example

Let us say that we want a slightly more relaxed policy than the standard `RExec` class. For example, if we're willing to allow files in `/tmp` to be written, we can subclass the `RExec` class:

```
class TmpWriterRExec(rexec.RExec):
    def r_open(self, file, mode='r', buf=-1):
        if mode in ('r', 'rb'):
            pass
        elif mode in ('w', 'wb', 'a', 'ab'):
            # check filename : must begin with /tmp/
            if file[:5] != '/tmp/':
                raise IOError("can't write outside /tmp")
            elif (string.find(file, '/../') >= 0 or
                  file[:3] == '/../' or file[-3:] == '/../'):
                raise IOError("'..' in filename forbidden")
            else: raise IOError("Illegal open() mode")
        return open(file, mode, buf)
```

Notice that the above code will occasionally forbid a perfectly valid filename; for example, code in the restricted environment won't be able to open a file called `/tmp/foo/../bar`. To fix this, the `r_open()` method would have to simplify the filename to `/tmp/bar`, which would require splitting apart the filename and performing various operations on it. In cases where security is at stake, it may be preferable to write simple code which is sometimes overly restrictive, instead of more general code that is also more complex and may harbor a subtle security hole.

## 29.2 Bastion — Restricting access to objects

Deprecated since version 2.6: The `Bastion` module has been removed in Python 3. Changed in version 2.3: Disabled module.

---

**Note:** The documentation has been left in place to help in reading old code that uses the module.

---

According to the dictionary, a bastion is “a fortified area or position”, or “something that is considered a stronghold.” It’s a suitable name for this module, which provides a way to forbid access to certain attributes of an object. It must always be used with the `rexec` module, in order to allow restricted-mode programs access to certain safe attributes of an object, while denying access to other, unsafe attributes.

`Bastion.Bastion(object[, filter[, name[, class ] ] ])`

Protect the object *object*, returning a bastion for the object. Any attempt to access one of the object’s attributes will have to be approved by the *filter* function; if the access is denied an `AttributeError` exception will be raised.

If present, *filter* must be a function that accepts a string containing an attribute name, and returns true if access to that attribute will be permitted; if *filter* returns false, the access is denied. The default filter denies access to any function beginning with an underscore (`'_'`). The bastion’s string representation will be `<Bastion for name>` if a value for *name* is provided; otherwise, `repr(object)` will be used.

*class*, if present, should be a subclass of `BastionClass`; see the code in `bastion.py` for the details. Overriding the default `BastionClass` will rarely be required.

**class** `Bastion.BastionClass(getfunc, name)`

Class which actually implements bastion objects. This is the default class used by `Bastion()`. The *getfunc* parameter is a function which returns the value of an attribute which should be exposed to the restricted execution environment when called with the name of the attribute as the only parameter. *name* is used to construct the `repr()` of the `BastionClass` instance.

**See Also:**

**Grail Home Page** Grail, an Internet browser written in Python, uses these modules to support Python applets. More information on the use of Python’s restricted execution mode in Grail is available on the Web site.



# IMPORTING MODULES

The modules described in this chapter provide new ways to import other Python modules and hooks for customizing the import process.

The full list of modules described in this chapter is:

## 30.1 `imp` — Access the `import` internals

This module provides an interface to the mechanisms used to implement the `import` statement. It defines the following constants and functions:

`imp.get_magic()`

Return the magic string value used to recognize byte-compiled code files (`.pyc` files). (This value may be different for each Python version.)

`imp.get_suffixes()`

Return a list of 3-element tuples, each describing a particular type of module. Each triple has the form `(suffix, mode, type)`, where `suffix` is a string to be appended to the module name to form the filename to search for, `mode` is the mode string to pass to the built-in `open()` function to open the file (this can be `'r'` for text files or `'rb'` for binary files), and `type` is the file type, which has one of the values `PY_SOURCE`, `PY_COMPILED`, or `C_EXTENSION`, described below.

`imp.find_module(name[, path])`

Try to find the module `name`. If `path` is omitted or `None`, the list of directory names given by `sys.path` is searched, but first a few special places are searched: the function tries to find a built-in module with the given name (`C_BUILTIN`), then a frozen module (`PY_FROZEN`), and on some systems some other places are looked in as well (on Windows, it looks in the registry which may point to a specific file).

Otherwise, `path` must be a list of directory names; each directory is searched for files with any of the suffixes returned by `get_suffixes()` above. Invalid names in the list are silently ignored (but all list items must be strings).

If search is successful, the return value is a 3-element tuple `(file, pathname, description)`:

`file` is an open file object positioned at the beginning, `pathname` is the pathname of the file found, and `description` is a 3-element tuple as contained in the list returned by `get_suffixes()` describing the kind of module found.

If the module does not live in a file, the returned `file` is `None`, `pathname` is the empty string, and the `description` tuple contains empty strings for its suffix and mode; the module type is indicated as given in parentheses above. If the search is unsuccessful, `ImportError` is raised. Other exceptions indicate problems with the arguments or environment.

If the module is a package, *file* is `None`, *pathname* is the package path and the last item in the *description* tuple is `PKG_DIRECTORY`.

This function does not handle hierarchical module names (names containing dots). In order to find *PM*, that is, submodule *M* of package *P*, use `find_module()` and `load_module()` to find and load package *P*, and then use `find_module()` with the *path* argument set to `P.__path__`. When *P* itself has a dotted name, apply this recipe recursively.

`imp.load_module(name, file, pathname, description)`

Load a module that was previously found by `find_module()` (or by an otherwise conducted search yielding compatible results). This function does more than importing the module: if the module was already imported, it is equivalent to a `reload()`! The *name* argument indicates the full module name (including the package name, if this is a submodule of a package). The *file* argument is an open file, and *pathname* is the corresponding file name; these can be `None` and `"`, respectively, when the module is a package or not being loaded from a file. The *description* argument is a tuple, as would be returned by `get_suffixes()`, describing what kind of module must be loaded.

If the load is successful, the return value is the module object; otherwise, an exception (usually `ImportError`) is raised.

**Important:** the caller is responsible for closing the *file* argument, if it was not `None`, even when an exception is raised. This is best done using a `try ... finally` statement.

`imp.new_module(name)`

Return a new empty module object called *name*. This object is *not* inserted in `sys.modules`.

`imp.lock_held()`

Return `True` if the import lock is currently held, else `False`. On platforms without threads, always return `False`.

On platforms with threads, a thread executing an import holds an internal lock until the import is complete. This lock blocks other threads from doing an import until the original import completes, which in turn prevents other threads from seeing incomplete module objects constructed by the original thread while in the process of completing its import (and the imports, if any, triggered by that).

`imp.acquire_lock()`

Acquire the interpreter's import lock for the current thread. This lock should be used by import hooks to ensure thread-safety when importing modules.

Once a thread has acquired the import lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

On platforms without threads, this function does nothing. New in version 2.3.

`imp.release_lock()`

Release the interpreter's import lock. On platforms without threads, this function does nothing. New in version 2.3.

The following constants with integer values, defined in this module, are used to indicate the search result of `find_module()`.

`imp.PY_SOURCE`

The module was found as a source file.

`imp.PY_COMPILED`

The module was found as a compiled code object file.

`imp.C_EXTENSION`

The module was found as dynamically loadable shared library.

`imp.PKG_DIRECTORY`

The module was found as a package directory.

**imp.C\_BUILTIN**

The module was found as a built-in module.

**imp.PY\_FROZEN**

The module was found as a frozen module (see `init_frozen()`).

The following constant and functions are obsolete; their functionality is available through `find_module()` or `load_module()`. They are kept around for backward compatibility:

**imp.SEARCH\_ERROR**

Unused.

**imp.init\_builtin** (*name*)

Initialize the built-in module called *name* and return its module object along with storing it in `sys.modules`. If the module was already initialized, it will be initialized *again*. Re-initialization involves the copying of the built-in module's `__dict__` from the cached module over the module's entry in `sys.modules`. If there is no built-in module called *name*, `None` is returned.

**imp.init\_frozen** (*name*)

Initialize the frozen module called *name* and return its module object. If the module was already initialized, it will be initialized *again*. If there is no frozen module called *name*, `None` is returned. (Frozen modules are modules written in Python whose compiled byte-code object is incorporated into a custom-built Python interpreter by Python's **freeze** utility. See `Tools/freeze/` for now.)

**imp.is\_builtin** (*name*)

Return 1 if there is a built-in module called *name* which can be initialized again. Return -1 if there is a built-in module called *name* which cannot be initialized again (see `init_builtin()`). Return 0 if there is no built-in module called *name*.

**imp.is\_frozen** (*name*)

Return `True` if there is a frozen module (see `init_frozen()`) called *name*, or `False` if there is no such module.

**imp.load\_compiled** (*name*, *pathname* [, *file* ])

Load and initialize a module implemented as a byte-compiled code file and return its module object. If the module was already initialized, it will be initialized *again*. The *name* argument is used to create or access a module object. The *pathname* argument points to the byte-compiled code file. The *file* argument is the byte-compiled code file, open for reading in binary mode, from the beginning. It must currently be a real file object, not a user-defined class emulating a file.

**imp.load\_dynamic** (*name*, *pathname* [, *file* ])

Load and initialize a module implemented as a dynamically loadable shared library and return its module object. If the module was already initialized, it will be initialized *again*. Re-initialization involves copying the `__dict__` attribute of the cached instance of the module over the value used in the module cached in `sys.modules`. The *pathname* argument must point to the shared library. The *name* argument is used to construct the name of the initialization function: an external C function called `initname()` in the shared library is called. The optional *file* argument is ignored. (Note: using shared libraries is highly system dependent, and not all systems support it.)

**imp.load\_source** (*name*, *pathname* [, *file* ])

Load and initialize a module implemented as a Python source file and return its module object. If the module was already initialized, it will be initialized *again*. The *name* argument is used to create or access a module object. The *pathname* argument points to the source file. The *file* argument is the source file, open for reading as text, from the beginning. It must currently be a real file object, not a user-defined class emulating a file. Note that if a properly matching byte-compiled file (with suffix `.pyc` or `.pyo`) exists, it will be used instead of parsing the given source file.

**class imp.NullImporter** (*path\_string*)

The `NullImporter` type is a **PEP 302** import hook that handles non-directory path strings by failing to find

any modules. Calling this type with an existing directory or empty string raises `ImportError`. Otherwise, a `NullImporter` instance is returned.

Python adds instances of this type to `sys.path_importer_cache` for any path entries that are not directories and are not handled by any other path hooks on `sys.path_hooks`. Instances have only one method:

**find\_module** (*fullname* [, *path* ])

This method always returns `None`, indicating that the requested module could not be found.

New in version 2.5.

### 30.1.1 Examples

The following function emulates what was the standard import statement up to Python 1.4 (no hierarchical module names). (This *implementation* wouldn't work in that version, since `find_module()` has been extended and `load_module()` has been added in 1.4.)

```
import imp
import sys

def __import__(name, globals=None, locals=None, fromlist=None):
    # Fast path: see if the module has already been imported.
    try:
        return sys.modules[name]
    except KeyError:
        pass

    # If any of the following calls raises an exception,
    # there's a problem we can't handle -- let the caller handle it.

    fp, pathname, description = imp.find_module(name)

    try:
        return imp.load_module(name, fp, pathname, description)
    finally:
        # Since we may exit via an exception, close fp explicitly.
        if fp:
            fp.close()
```

A more complete example that implements hierarchical module names and includes a `reload()` function can be found in the module `knee`. The `knee` module can be found in `Demo/imputil/` in the Python source distribution.

## 30.2 `importlib` – Convenience wrappers for `__import__()`

New in version 2.7. This module is a minor subset of what is available in the more full-featured package of the same name from Python 3.1 that provides a complete implementation of `import`. What is here has been provided to help ease in transitioning from 2.7 to 3.1.

`importlib.import_module` (*name*, *package=None*)

Import a module. The *name* argument specifies what module to import in absolute or relative terms (e.g. either `pkg.mod` or `..mod`). If the name is specified in relative terms, then the *package* argument must be specified to the package which is to act as the anchor for resolving the package name (e.g. `import_module('..mod', 'pkg.subpkg')` will import `pkg.mod`). The specified module will be inserted into `sys.modules` and returned.

## 30.3 `imputil` — Import utilities

Deprecated since version 2.6: The `imputil` module has been removed in Python 3. This module provides a very handy and useful mechanism for custom `import` hooks. Compared to the older `ihooks` module, `imputil` takes a dramatically simpler and more straight-forward approach to custom `import` functions.

**class** `imputil.ImportManager` (`[fs_imp]`)

Manage the import process.

**install** (`[namespace]`)

Install this `ImportManager` into the specified namespace.

**uninstall** ()

Restore the previous import mechanism.

**add\_suffix** (`suffix, importFunc`)

Undocumented.

**class** `imputil.Importer`

Base class for replacing standard import functions.

**import\_top** (`name`)

Import a top-level module.

**get\_code** (`parent, modname, fqname`)

Find and retrieve the code for the given module.

*parent* specifies a parent module to define a context for importing. It may be `None`, indicating no particular context for the search.

*modname* specifies a single module (not dotted) within the parent.

*fqname* specifies the fully-qualified module name. This is a (potentially) dotted name from the “root” of the module namespace down to the *modname*.

If there is no parent, then `modname==fqname`.

This method should return `None`, or a 3-tuple.

- If the module was not found, then `None` should be returned.
- The first item of the 2- or 3-tuple should be the integer 0 or 1, specifying whether the module that was found is a package or not.
- The second item is the code object for the module (it will be executed within the new module’s namespace). This item can also be a fully-loaded module object (e.g. loaded from a shared lib).
- The third item is a dictionary of name/value pairs that will be inserted into new module before the code object is executed. This is provided in case the module’s code expects certain values (such as where the module was found). When the second item is a module object, then these names/values will be inserted *after* the module has been loaded/initialized.

**class** `imputil.BuiltinImporter`

Emulate the import mechanism for built-in and frozen modules. This is a sub-class of the `Importer` class.

**get\_code** (`parent, modname, fqname`)

Undocumented.

`imputil.py_suffix_importer` (`filename, info, fqname`)

Undocumented.

**class** `imputil.DynLoadSuffixImporter` (`[desc]`)

Undocumented.

```
import_file(filename, finfo, fqname)
Undocumented.
```

### 30.3.1 Examples

This is a re-implementation of hierarchical module import.

This code is intended to be read, not executed. However, it does work – all you need to do to enable it is “import knee”.

(The name is a pun on the clunkier predecessor of this module, “ni”.)

```
import sys, imp, __builtin__

# Replacement for __import__()
def import_hook(name, globals=None, locals=None, fromlist=None):
    parent = determine_parent(globals)
    q, tail = find_head_package(parent, name)
    m = load_tail(q, tail)
    if not fromlist:
        return q
    if hasattr(m, "__path__"):
        ensure_fromlist(m, fromlist)
    return m

def determine_parent(globals):
    if not globals or not globals.has_key("__name__"):
        return None
    pname = globals['__name__']
    if globals.has_key("__path__"):
        parent = sys.modules[pname]
        assert globals is parent.__dict__
        return parent
    if '.' in pname:
        i = pname.rfind('.')
        pname = pname[:i]
        parent = sys.modules[pname]
        assert parent.__name__ == pname
        return parent
    return None

def find_head_package(parent, name):
    if '.' in name:
        i = name.find('.')
        head = name[:i]
        tail = name[i+1:]
    else:
        head = name
        tail = ""
    if parent:
        qname = "%s.%s" % (parent.__name__, head)
    else:
        qname = head
    q = import_module(head, qname, parent)
    if q: return q, tail
```

```

    if parent:
        qname = head
        parent = None
        q = import_module(head, qname, parent)
        if q: return q, tail
    raise ImportError("No module named " + qname)

def load_tail(q, tail):
    m = q
    while tail:
        i = tail.find('.')
        if i < 0: i = len(tail)
        head, tail = tail[:i], tail[i+1:]
        mname = "%s.%s" % (m.__name__, head)
        m = import_module(head, mname, m)
        if not m:
            raise ImportError("No module named " + mname)
    return m

def ensure_fromlist(m, fromlist, recursive=0):
    for sub in fromlist:
        if sub == "*":
            if not recursive:
                try:
                    all = m.__all__
                except AttributeError:
                    pass
            else:
                ensure_fromlist(m, all, 1)
            continue
        if sub != "*" and not hasattr(m, sub):
            subname = "%s.%s" % (m.__name__, sub)
            submod = import_module(sub, subname, m)
            if not submod:
                raise ImportError("No module named " + subname)

def import_module(partname, fqname, parent):
    try:
        return sys.modules[fqname]
    except KeyError:
        pass
    try:
        fp, pathname, stuff = imp.find_module(partname,
                                              parent and parent.__path__)
    except ImportError:
        return None
    try:
        m = imp.load_module(fqname, fp, pathname, stuff)
    finally:
        if fp: fp.close()
    if parent:
        setattr(parent, partname, m)
    return m

```

```
# Replacement for reload()
def reload_hook(module):
    name = module.__name__
    if '.' not in name:
        return import_module(name, name, None)
    i = name.rfind('.')
    pname = name[:i]
    parent = sys.modules[pname]
    return import_module(name[i+1:], name, parent)

# Save the original hooks
original_import = __builtin__.__import__
original_reload = __builtin__.reload

# Now install our hooks
__builtin__.__import__ = import_hook
__builtin__.reload = reload_hook
```

Also see the `importers` module (which can be found in `Demo/importutil/` in the Python source distribution) for additional examples.

## 30.4 zipimport — Import modules from Zip archives

New in version 2.3. This module adds the ability to import Python modules (`*.py`, `*.py[co]`) and packages from ZIP-format archives. It is usually not needed to use the `zipimport` module explicitly; it is automatically used by the built-in `import` mechanism for `sys.path` items that are paths to ZIP archives.

Typically, `sys.path` is a list of directory names as strings. This module also allows an item of `sys.path` to be a string naming a ZIP file archive. The ZIP archive can contain a subdirectory structure to support package imports, and a path within the archive can be specified to only import from a subdirectory. For example, the path `/tmp/example.zip/lib/` would only import from the `lib/` subdirectory within the archive.

Any files may be present in the ZIP archive, but only files `.py` and `.py[co]` are available for import. ZIP import of dynamic modules (`.pyd`, `.so`) is disallowed. Note that if an archive only contains `.py` files, Python will not attempt to modify the archive by adding the corresponding `.pyc` or `.pyo` file, meaning that if a ZIP archive doesn't contain `.pyc` files, importing may be rather slow.

Using the built-in `reload()` function will fail if called on a module loaded from a ZIP archive; it is unlikely that `reload()` would be needed, since this would imply that the ZIP has been altered during runtime.

ZIP archives with an archive comment are currently not supported.

### See Also:

**PKZIP Application Note** Documentation on the ZIP file format by Phil Katz, the creator of the format and algorithms used.

**PEP 273 - Import Modules from Zip Archives** Written by James C. Ahlstrom, who also provided an implementation. Python 2.3 follows the specification in PEP 273, but uses an implementation written by Just van Rossum that uses the import hooks described in PEP 302.

**PEP 302 - New Import Hooks** The PEP to add the import hooks that help this module work.

This module defines an exception:

**exception** `zipimport.ZipImportError`

Exception raised by `zipimporter` objects. It's a subclass of `ImportError`, so it can be caught as `ImportError`, too.

### 30.4.1 zipimporter Objects

`zipimporter` is the class for importing ZIP files.

**class** `zipimport.zipimporter` (*archivepath*)

Create a new `zipimporter` instance. *archivepath* must be a path to a ZIP file, or to a specific path within a ZIP file. For example, an *archivepath* of `foo/bar.zip/lib` will look for modules in the `lib` directory inside the ZIP file `foo/bar.zip` (provided that it exists).

`ZipImportError` is raised if *archivepath* doesn't point to a valid ZIP archive.

**find\_module** (*fullname* [, *path* ])

Search for a module specified by *fullname*. *fullname* must be the fully qualified (dotted) module name. It returns the `zipimporter` instance itself if the module was found, or `None` if it wasn't. The optional *path* argument is ignored—it's there for compatibility with the importer protocol.

**get\_code** (*fullname*)

Return the code object for the specified module. Raise `ZipImportError` if the module couldn't be found.

**get\_data** (*pathname*)

Return the data associated with *pathname*. Raise `IOError` if the file wasn't found.

**get\_filename** (*fullname*)

Return the value `__file__` would be set to if the specified module was imported. Raise `ZipImportError` if the module couldn't be found.

New in version 2.7.

**get\_source** (*fullname*)

Return the source code for the specified module. Raise `ZipImportError` if the module couldn't be found, return `None` if the archive does contain the module, but has no source for it.

**is\_package** (*fullname*)

Return True if the module specified by *fullname* is a package. Raise `ZipImportError` if the module couldn't be found.

**load\_module** (*fullname*)

Load the module specified by *fullname*. *fullname* must be the fully qualified (dotted) module name. It returns the imported module, or raises `ZipImportError` if it wasn't found.

**archive**

The file name of the importer's associated ZIP file, without a possible subpath.

**prefix**

The subpath within the ZIP file where modules are searched. This is the empty string for `zipimporter` objects which point to the root of the ZIP file.

The `archive` and `prefix` attributes, when combined with a slash, equal the original *archivepath* argument given to the `zipimporter` constructor.

### 30.4.2 Examples

Here is an example that imports a module from a ZIP archive - note that the `zipimport` module is not explicitly used.

```
$ unzip -l /tmp/example.zip
Archive:  /tmp/example.zip
  Length      Date    Time    Name
-----
      8467   11-26-02  22:30   jwzthreading.py
-----
      8467                   1 file
$ ./python
Python 2.3 (#1, Aug 1 2003, 19:54:32)
>>> import sys
>>> sys.path.insert(0, '/tmp/example.zip') # Add .zip file to front of path
>>> import jwzthreading
>>> jwzthreading.__file__
'/tmp/example.zip/jwzthreading.py'
```

### 30.5 pkgutil — Package extension utility

New in version 2.3. **Source code:** [Lib/pkgutil.py](#)

---

This module provides utilities for the import system, in particular package support.

`pkgutil.extend_path(path, name)`

Extend the search path for the modules which comprise a package. Intended use is to place the following code in a package's `__init__.py`:

```
from pkgutil import extend_path
__path__ = extend_path(__path__, __name__)
```

This will add to the package's `__path__` all subdirectories of directories on `sys.path` named after the package. This is useful if one wants to distribute different parts of a single logical package as multiple directories.

It also looks for `*.pkg` files beginning where `*` matches the `name` argument. This feature is similar to `*.pth` files (see the [site](#) module for more information), except that it doesn't special-case lines starting with `import`. A `*.pkg` file is trusted at face value: apart from checking for duplicates, all entries found in a `*.pkg` file are added to the path, regardless of whether they exist on the filesystem. (This is a feature.)

If the input path is not a list (as is the case for frozen packages) it is returned unchanged. The input path is not modified; an extended copy is returned. Items are only appended to the copy at the end.

It is assumed that `sys.path` is a sequence. Items of `sys.path` that are not (Unicode or 8-bit) strings referring to existing directories are ignored. Unicode items on `sys.path` that cause errors when used as filenames may cause this function to raise an exception (in line with `os.path.isdir()` behavior).

**class** `pkgutil.ImpImporter` (*dirname=None*)

**PEP 302** Importer that wraps Python's "classic" import algorithm.

If *dirname* is a string, a **PEP 302** importer is created that searches that directory. If *dirname* is `None`, a **PEP 302** importer is created that searches the current `sys.path`, plus any modules that are frozen or built-in.

Note that `ImpImporter` does not currently support being used by placement on `sys.meta_path`.

**class** `pkgutil.ImpLoader` (*fullname, file, filename, etc*)

**PEP 302** Loader that wraps Python's "classic" import algorithm.

`pkgutil.find_loader(fullname)`

Find a **PEP 302** “loader” object for *fullname*.

If *fullname* contains dots, *path* must be the containing package’s `__path__`. Returns `None` if the module cannot be found or imported. This function uses `iter_importers()`, and is thus subject to the same limitations regarding platform-specific special import locations such as the Windows registry.

`pkgutil.get_importer(path_item)`

Retrieve a **PEP 302** importer for the given *path\_item*.

The returned importer is cached in `sys.path_importer_cache` if it was newly created by a path hook.

If there is no importer, a wrapper around the basic import machinery is returned. This wrapper is never inserted into the importer cache (`None` is inserted instead).

The cache (or part of it) can be cleared manually if a rescan of `sys.path_hooks` is necessary.

`pkgutil.get_loader(module_or_name)`

Get a **PEP 302** “loader” object for *module\_or\_name*.

If the module or package is accessible via the normal import mechanism, a wrapper around the relevant part of that machinery is returned. Returns `None` if the module cannot be found or imported. If the named module is not already imported, its containing package (if any) is imported, in order to establish the package `__path__`.

This function uses `iter_importers()`, and is thus subject to the same limitations regarding platform-specific special import locations such as the Windows registry.

`pkgutil.iter_importers(fullname='')`

Yield **PEP 302** importers for the given module name.

If *fullname* contains a `.`, the importers will be for the package containing *fullname*, otherwise they will be importers for `sys.meta_path`, `sys.path`, and Python’s “classic” import machinery, in that order. If the named module is in a package, that package is imported as a side effect of invoking this function.

Non- **PEP 302** mechanisms (e.g. the Windows registry) used by the standard import machinery to find files in alternative locations are partially supported, but are searched *after* `sys.path`. Normally, these locations are searched *before* `sys.path`, preventing `sys.path` entries from shadowing them.

For this to cause a visible difference in behaviour, there must be a module or package name that is accessible via both `sys.path` and one of the non- **PEP 302** file system mechanisms. In this case, the emulation will find the former version, while the builtin import mechanism will find the latter.

Items of the following types can be affected by this discrepancy: `imp.C_EXTENSION`, `imp.PY_SOURCE`, `imp.PY_COMPILED`, `imp.PKG_DIRECTORY`.

`pkgutil.iter_modules(path=None, prefix='')`

Yields (`module_loader`, `name`, `ispkg`) for all submodules on *path*, or, if *path* is `None`, all top-level modules on `sys.path`.

*path* should be either `None` or a list of paths to look for modules in.

*prefix* is a string to output on the front of every module name on output.

`pkgutil.walk_packages(path=None, prefix='', onerror=None)`

Yields (`module_loader`, `name`, `ispkg`) for all modules recursively on *path*, or, if *path* is `None`, all accessible modules.

*path* should be either `None` or a list of paths to look for modules in.

*prefix* is a string to output on the front of every module name on output.

Note that this function must import all *packages* (not all modules!) on the given *path*, in order to access the `__path__` attribute to find submodules.

`onerror` is a function which gets called with one argument (the name of the package which was being imported) if any exception occurs while trying to import a package. If no `onerror` function is supplied, `ImportErrors` are caught and ignored, while all other exceptions are propagated, terminating the search.

Examples:

```
# list all modules python can access
walk_packages()

# list all submodules of ctypes
walk_packages(ctypes.__path__, ctypes.__name__ + '.')
```

`pkgutil.get_data(package, resource)`

Get a resource from a package.

This is a wrapper for the [PEP 302](#) loader `get_data()` API. The `package` argument should be the name of a package, in standard module format (`foo.bar`). The `resource` argument should be in the form of a relative filename, using `/` as the path separator. The parent directory name `..` is not allowed, and nor is a rooted name (starting with a `/`).

The function returns a binary string that is the contents of the specified resource.

For packages located in the filesystem, which have already been imported, this is the rough equivalent of:

```
d = os.path.dirname(sys.modules[package].__file__)
data = open(os.path.join(d, resource), 'rb').read()
```

If the package cannot be located or loaded, or it uses a [PEP 302](#) loader which does not support `get_data()`, then `None` is returned. New in version 2.6.

## 30.6 modulefinder — Find modules used by a script

New in version 2.3. **Source code:** [Lib/modulefinder.py](#)

---

This module provides a `ModuleFinder` class that can be used to determine the set of modules imported by a script. `modulefinder.py` can also be run as a script, giving the filename of a Python script as its argument, after which a report of the imported modules will be printed.

`modulefinder.AddPackagePath(pkg_name, path)`

Record that the package named `pkg_name` can be found in the specified `path`.

`modulefinder.ReplacePackage(oldname, newname)`

Allows specifying that the module named `oldname` is in fact the package named `newname`. The most common usage would be to handle how the `_xmlplus` package replaces the `xml` package.

**class** `modulefinder.ModuleFinder` (`[path=None, debug=0, excludes=[], replace_paths=[]]`)

This class provides `run_script()` and `report()` methods to determine the set of modules imported by a script. `path` can be a list of directories to search for modules; if not specified, `sys.path` is used. `debug` sets the debugging level; higher values make the class print debugging messages about what it's doing. `excludes` is a list of module names to exclude from the analysis. `replace_paths` is a list of (`oldpath`, `newpath`) tuples that will be replaced in module paths.

**report()**

Print a report to standard output that lists the modules imported by the script and their paths, as well as modules that are missing or seem to be missing.

**run\_script** (*pathname*)

Analyze the contents of the *pathname* file, which must contain Python code.

**modules**

A dictionary mapping module names to modules. See *Example usage of ModuleFinder*

### 30.6.1 Example usage of ModuleFinder

The script that is going to get analyzed later on (bacon.py):

```
import re, itertools

try:
    import baconhameggs
except ImportError:
    pass

try:
    import guido.python.ham
except ImportError:
    pass
```

The script that will output the report of bacon.py:

```
from modulefinder import ModuleFinder

finder = ModuleFinder()
finder.run_script('bacon.py')

print 'Loaded modules:'
for name, mod in finder.modules.iteritems():
    print '%s: ' % name,
    print ','.join(mod.globalnames.keys()[:3])

print '-'*50
print 'Modules not imported:'
print '\n'.join(finder.badmodules.iterkeys())
```

Sample output (may vary depending on the architecture):

```
Loaded modules:
_types:
copy_reg:  _inverted_registry, _slotnames, __all__
sre_compile:  isstring, _sre, _optimize_unicode
_sre:
sre_constants:  REPEAT_ONE, makedict, AT_END_LINE
sys:
re:  __module__, finditer, _expand
itertools:
__main__:  re, itertools, baconhameggs
sre_parse:  __getslice__, _PATTERNENDERS, SRE_FLAG_UNICODE
array:
types:  __module__, IntType, TypeType
-----
Modules not imported:
```

guido.python.ham  
baconhameggs

## 30.7 `runpy` — Locating and executing Python modules

New in version 2.5. **Source code:** [Lib/runpy.py](#)

---

The `runpy` module is used to locate and run Python modules without importing them first. Its main use is to implement the `-m` command line switch that allows scripts to be located using the Python module namespace rather than the filesystem.

The `runpy` module provides two functions:

`runpy.run_module(mod_name, init_globals=None, run_name=None, alter_sys=False)`

Execute the code of the specified module and return the resulting module globals dictionary. The module's code is first located using the standard import mechanism (refer to [PEP 302](#) for details) and then executed in a fresh module namespace.

If the supplied module name refers to a package rather than a normal module, then that package is imported and the `__main__` submodule within that package is then executed and the resulting module globals dictionary returned.

The optional dictionary argument `init_globals` may be used to pre-populate the module's globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by `run_module()`.

The special global variables `__name__`, `__file__`, `__loader__` and `__package__` are set in the globals dictionary before the module code is executed (Note that this is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

`__name__` is set to `run_name` if this optional argument is not `None`, to `mod_name + '.__main__'` if the named module is a package and to the `mod_name` argument otherwise.

`__file__` is set to the name provided by the module loader. If the loader does not make filename information available, this variable is set to `None`.

`__loader__` is set to the [PEP 302](#) module loader used to retrieve the code for the module (This loader may be a wrapper around the standard import mechanism).

`__package__` is set to `mod_name` if the named module is a package and to `mod_name.rpartition('.')[0]` otherwise.

If the argument `alter_sys` is supplied and evaluates to `True`, then `sys.argv[0]` is updated with the value of `__file__` and `sys.modules[__name__]` is updated with a temporary module object for the module being executed. Both `sys.argv[0]` and `sys.modules[__name__]` are restored to their original values before the function returns.

Note that this manipulation of `sys` is not thread-safe. Other threads may see the partially initialised module, as well as the altered list of arguments. It is recommended that the `sys` module be left alone when invoking this function from threaded code. Changed in version 2.7: Added ability to execute packages by looking for a `__main__` submodule

`runpy.run_path(file_path, init_globals=None, run_name=None)`

Execute the code at the named filesystem location and return the resulting module globals dictionary. As with a script name supplied to the CPython command line, the supplied path may refer to a Python source file, a compiled bytecode file or a valid `sys.path` entry containing a `__main__` module (e.g. a zipfile containing a top-level `__main__.py` file).

For a simple script, the specified code is simply executed in a fresh module namespace. For a valid `sys.path` entry (typically a zipfile or directory), the entry is first added to the beginning of `sys.path`. The function then looks for and executes a `__main__` module using the updated path. Note that there is no special protection against invoking an existing `__main__` entry located elsewhere on `sys.path` if there is no such module at the specified location.

The optional dictionary argument `init_globals` may be used to pre-populate the module's globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by `run_path()`.

The special global variables `__name__`, `__file__`, `__loader__` and `__package__` are set in the globals dictionary before the module code is executed (Note that this is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

`__name__` is set to `run_name` if this optional argument is not `None` and to `'<run_path>'` otherwise.

`__file__` is set to the name provided by the module loader. If the loader does not make filename information available, this variable is set to `None`. For a simple script, this will be set to `file_path`.

`__loader__` is set to the **PEP 302** module loader used to retrieve the code for the module (This loader may be a wrapper around the standard import mechanism). For a simple script, this will be set to `None`.

`__package__` is set to `__name__.rpartition('.')[0]`.

A number of alterations are also made to the `sys` module. Firstly, `sys.path` may be altered as described above. `sys.argv[0]` is updated with the value of `file_path` and `sys.modules[__name__]` is updated with a temporary module object for the module being executed. All modifications to items in `sys` are reverted before the function returns.

Note that, unlike `run_module()`, the alterations made to `sys` are not optional in this function as these adjustments are essential to allowing the execution of `sys.path` entries. As the thread-safety limitations still apply, use of this function in threaded code should be either serialised with the import lock or delegated to a separate process. New in version 2.7.

#### See Also:

**PEP 338 - Executing modules as scripts** PEP written and implemented by Nick Coghlan.

**PEP 366 - Main module explicit relative imports** PEP written and implemented by Nick Coghlan.

*using-on-general* - CPython command line details



# PYTHON LANGUAGE SERVICES

Python provides a number of modules to assist in working with the Python language. These modules support tokenizing, parsing, syntax analysis, bytecode disassembly, and various other facilities.

These modules include:

## 31.1 `parser` — Access Python parse trees

The `parser` module provides an interface to Python's internal parser and byte-code compiler. The primary purpose for this interface is to allow Python code to edit the parse tree of a Python expression and create executable code from this. This is better than trying to parse and modify an arbitrary Python code fragment as a string because parsing is performed in a manner identical to the code forming the application. It is also faster.

---

**Note:** From Python 2.5 onward, it's much more convenient to cut in at the Abstract Syntax Tree (AST) generation and compilation stage, using the `ast` module.

The `parser` module exports the names documented here also with “st” replaced by “ast”; this is a legacy from the time when there was no other AST and has nothing to do with the AST found in Python 2.5. This is also the reason for the functions' keyword arguments being called *ast*, not *st*. The “ast” functions have been removed in Python 3.

---

There are a few things to note about this module which are important to making use of the data structures created. This is not a tutorial on editing the parse trees for Python code, but some examples of using the `parser` module are presented.

Most importantly, a good understanding of the Python grammar processed by the internal parser is required. For full information on the language syntax, refer to *reference-index*. The parser itself is created from a grammar specification defined in the file `Grammar/Grammar` in the standard Python distribution. The parse trees stored in the ST objects created by this module are the actual output from the internal parser when created by the `expr()` or `suite()` functions, described below. The ST objects created by `sequence2st()` faithfully simulate those structures. Be aware that the values of the sequences which are considered “correct” will vary from one version of Python to another as the formal grammar for the language is revised. However, transporting code from one Python version to another as source text will always allow correct parse trees to be created in the target version, with the only restriction being that migrating to an older version of the interpreter will not support more recent language constructs. The parse trees are not typically compatible from one version to another, whereas source code has always been forward-compatible.

Each element of the sequences returned by `st2list()` or `st2tuple()` has a simple form. Sequences representing non-terminal elements in the grammar always have a length greater than one. The first element is an integer which identifies a production in the grammar. These integers are given symbolic names in the C header file `Include/graminit.h` and the Python module `symbol`. Each additional element of the sequence represents a component of the production as recognized in the input string: these are always sequences which have the same form as the parent. An important aspect of this structure which should be noted is that keywords used to identify the parent

node type, such as the keyword `if` in an `if_stmt`, are included in the node tree without any special treatment. For example, the `if` keyword is represented by the tuple `(1, 'if')`, where `1` is the numeric value associated with all `NAME` tokens, including variable and function names defined by the user. In an alternate form returned when line number information is requested, the same token might be represented as `(1, 'if', 12)`, where the `12` represents the line number at which the terminal symbol was found.

Terminal elements are represented in much the same way, but without any child elements and the addition of the source text which was identified. The example of the `if` keyword above is representative. The various types of terminal symbols are defined in the C header file `Include/token.h` and the Python module `token`.

The ST objects are not required to support the functionality of this module, but are provided for three purposes: to allow an application to amortize the cost of processing complex parse trees, to provide a parse tree representation which conserves memory space when compared to the Python list or tuple representation, and to ease the creation of additional modules in C which manipulate parse trees. A simple “wrapper” class may be created in Python to hide the use of ST objects.

The `parser` module defines functions for a few distinct purposes. The most important purposes are to create ST objects and to convert ST objects to other representations such as parse trees and compiled code objects, but there are also functions which serve to query the type of parse tree represented by an ST object.

### See Also:

**Module `symbol`** Useful constants representing internal nodes of the parse tree.

**Module `token`** Useful constants representing leaf nodes of the parse tree and functions for testing node values.

### 31.1.1 Creating ST Objects

ST objects may be created from source code or from a parse tree. When creating an ST object from source, different functions are used to create the `'eval'` and `'exec'` forms.

`parser.expr(source)`

The `expr()` function parses the parameter `source` as if it were an input to `compile(source, 'file.py', 'eval')`. If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

`parser.suite(source)`

The `suite()` function parses the parameter `source` as if it were an input to `compile(source, 'file.py', 'exec')`. If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

`parser.sequence2st(sequence)`

This function accepts a parse tree represented as a sequence and builds an internal representation if possible. If it can validate that the tree conforms to the Python grammar and all nodes are valid node types in the host version of Python, an ST object is created from the internal representation and returned to the caller. If there is a problem creating the internal representation, or if the tree cannot be validated, a `ParserError` exception is raised. An ST object created this way should not be assumed to compile correctly; normal exceptions raised by compilation may still be initiated when the ST object is passed to `compilest()`. This may indicate problems not related to syntax (such as a `MemoryError` exception), but may also be due to constructs such as the result of parsing `del f(0)`, which escapes the Python parser but is checked by the bytecode compiler.

Sequences representing terminal tokens may be represented as either two-element lists of the form `(1, 'name')` or as three-element lists of the form `(1, 'name', 56)`. If the third element is present, it is assumed to be a valid line number. The line number may be specified for any subset of the terminal symbols in the input tree.

`parser.tuple2st(sequence)`

This is the same function as `sequence2st()`. This entry point is maintained for backward compatibility.

### 31.1.2 Converting ST Objects

ST objects, regardless of the input used to create them, may be converted to parse trees represented as list- or tuple-trees, or may be compiled into executable code objects. Parse trees may be extracted with or without line numbering information.

`parser.st2list` (*ast* [, *line\_info* ])

This function accepts an ST object from the caller in *ast* and returns a Python list representing the equivalent parse tree. The resulting list representation can be used for inspection or the creation of a new parse tree in list form. This function does not fail so long as memory is available to build the list representation. If the parse tree will only be used for inspection, `st2tuple()` should be used instead to reduce memory consumption and fragmentation. When the list representation is required, this function is significantly faster than retrieving a tuple representation and converting that to nested lists.

If *line\_info* is true, line number information will be included for all terminal tokens as a third element of the list representing the token. Note that the line number provided specifies the line on which the token *ends*. This information is omitted if the flag is false or omitted.

`parser.st2tuple` (*ast* [, *line\_info* ])

This function accepts an ST object from the caller in *ast* and returns a Python tuple representing the equivalent parse tree. Other than returning a tuple instead of a list, this function is identical to `st2list()`.

If *line\_info* is true, line number information will be included for all terminal tokens as a third element of the list representing the token. This information is omitted if the flag is false or omitted.

`parser.compilest` (*ast*, *filename*= '<syntax-tree>')

The Python byte compiler can be invoked on an ST object to produce code objects which can be used as part of an `exec` statement or a call to the built-in `eval()` function. This function provides the interface to the compiler, passing the internal parse tree from *ast* to the parser, using the source file name specified by the *filename* parameter. The default value supplied for *filename* indicates that the source was an ST object.

Compiling an ST object may result in exceptions related to compilation; an example would be a `SyntaxError` caused by the parse tree for `del f(0)`: this statement is considered legal within the formal grammar for Python but is not a legal language construct. The `SyntaxError` raised for this condition is actually generated by the Python byte-compiler normally, which is why it can be raised at this point by the `parser` module. Most causes of compilation failure can be diagnosed programmatically by inspection of the parse tree.

### 31.1.3 Queries on ST Objects

Two functions are provided which allow an application to determine if an ST was created as an expression or a suite. Neither of these functions can be used to determine if an ST was created from source code via `expr()` or `suite()` or from a parse tree via `sequence2st()`.

`parser.isexpr` (*ast*)

When *ast* represents an 'eval' form, this function returns true, otherwise it returns false. This is useful, since code objects normally cannot be queried for this information using existing built-in functions. Note that the code objects created by `compilest()` cannot be queried like this either, and are identical to those created by the built-in `compile()` function.

`parser.issuite` (*ast*)

This function mirrors `isexpr()` in that it reports whether an ST object represents an 'exec' form, commonly known as a "suite." It is not safe to assume that this function is equivalent to `not isexpr(ast)`, as additional syntactic fragments may be supported in the future.

### 31.1.4 Exceptions and Error Handling

The parser module defines a single exception, but may also pass other built-in exceptions from other portions of the Python runtime environment. See each function for information about the exceptions it can raise.

#### **exception** `parser.ParserError`

Exception raised when a failure occurs within the parser module. This is generally produced for validation failures rather than the built-in `SyntaxError` raised during normal parsing. The exception argument is either a string describing the reason of the failure or a tuple containing a sequence causing the failure from a parse tree passed to `sequence2st()` and an explanatory string. Calls to `sequence2st()` need to be able to handle either type of exception, while calls to other functions in the module will only need to be aware of the simple string values.

Note that the functions `compilest()`, `expr()`, and `suite()` may raise exceptions which are normally raised by the parsing and compilation process. These include the built in exceptions `MemoryError`, `OverflowError`, `SyntaxError`, and `SystemError`. In these cases, these exceptions carry all the meaning normally associated with them. Refer to the descriptions of each function for detailed information.

### 31.1.5 ST Objects

Ordered and equality comparisons are supported between ST objects. Pickling of ST objects (using the `pickle` module) is also supported.

#### **parser.STType**

The type of the objects returned by `expr()`, `suite()` and `sequence2st()`.

ST objects have the following methods:

`ST.compile([filename])`  
Same as `compilest(st, filename)`.

`ST.isexpr()`  
Same as `isexpr(st)`.

`ST.issuite()`  
Same as `issuite(st)`.

`ST.tolist([line_info])`  
Same as `st2list(st, line_info)`.

`ST.totuple([line_info])`  
Same as `st2tuple(st, line_info)`.

### 31.1.6 Example: Emulation of `compile()`

While many useful operations may take place between parsing and bytecode generation, the simplest operation is to do nothing. For this purpose, using the `parser` module to produce an intermediate data structure is equivalent to the code

```
>>> code = compile('a + 5', 'file.py', 'eval')
>>> a = 5
>>> eval(code)
10
```

The equivalent operation using the `parser` module is somewhat longer, and allows the intermediate internal parse tree to be retained as an ST object:

```
>>> import parser
>>> st = parser.expr('a + 5')
>>> code = st.compile('file.py')
>>> a = 5
>>> eval(code)
10
```

An application which needs both ST and code objects can package this code into readily available functions:

```
import parser

def load_suite(source_string):
    st = parser.suite(source_string)
    return st, st.compile()

def load_expression(source_string):
    st = parser.expr(source_string)
    return st, st.compile()
```

## 31.2 ast — Abstract Syntax Trees

New in version 2.5: The low-level `_ast` module containing only the node classes. New in version 2.6: The high-level `ast` module containing all helpers. **Source code:** [Lib/ast.py](#)

The `ast` module helps Python applications to process trees of the Python abstract syntax grammar. The abstract syntax itself might change with each Python release; this module helps to find out programmatically what the current grammar looks like.

An abstract syntax tree can be generated by passing `ast.PyCF_ONLY_AST` as a flag to the `compile()` built-in function, or using the `parse()` helper provided in this module. The result will be a tree of objects whose classes all inherit from `ast.AST`. An abstract syntax tree can be compiled into a Python code object using the built-in `compile()` function.

### 31.2.1 Node classes

#### class `ast.AST`

This is the base of all AST node classes. The actual node classes are derived from the `Parser/Python.asdl` file, which is reproduced *below*. They are defined in the `_ast` C module and re-exported in `ast`.

There is one class defined for each left-hand side symbol in the abstract grammar (for example, `ast.stmt` or `ast.expr`). In addition, there is one class defined for each constructor on the right-hand side; these classes inherit from the classes for the left-hand side trees. For example, `ast.BinOp` inherits from `ast.expr`. For production rules with alternatives (aka “sums”), the left-hand side class is abstract: only instances of specific constructor nodes are ever created.

#### `_fields`

Each concrete class has an attribute `_fields` which gives the names of all child nodes.

Each instance of a concrete class has one attribute for each child node, of the type as defined in the grammar. For example, `ast.BinOp` instances have an attribute `left` of type `ast.expr`.

If these attributes are marked as optional in the grammar (using a question mark), the value might be `None`. If the attributes can have zero-or-more values (marked with an asterisk), the values are represented

as Python lists. All possible attributes must be present and have valid values when compiling an AST with `compile()`.

### **lineno**

### **col\_offset**

Instances of `ast.expr` and `ast.stmt` subclasses have `lineno` and `col_offset` attributes. The `lineno` is the line number of source text (1-indexed so the first line is line 1) and the `col_offset` is the UTF-8 byte offset of the first token that generated the node. The UTF-8 offset is recorded because the parser uses UTF-8 internally.

The constructor of a class `ast.T` parses its arguments as follows:

- If there are positional arguments, there must be as many as there are items in `T.__fields`; they will be assigned as attributes of these names.
- If there are keyword arguments, they will set the attributes of the same names to the given values.

For example, to create and populate an `ast.UnaryOp` node, you could use

```
node = ast.UnaryOp()
node.op = ast.USub()
node.operand = ast.Num()
node.operand.n = 5
node.operand.lineno = 0
node.operand.col_offset = 0
node.lineno = 0
node.col_offset = 0
```

or the more compact

```
node = ast.UnaryOp(ast.USub(), ast.Num(5, lineno=0, col_offset=0),
                  lineno=0, col_offset=0)
```

New in version 2.6: The constructor as explained above was added. In Python 2.5 nodes had to be created by calling the class constructor without arguments and setting the attributes afterwards.

## 31.2.2 Abstract Grammar

The module defines a string constant `__version__` which is the decimal Subversion revision number of the file shown below.

The abstract grammar is currently defined as follows:

```
-- ASDL's five builtin types are identifier, int, string, object, bool
```

```
module Python version "$Revision$"
{
    mod = Module(stmt* body)
        | Interactive(stmt* body)
        | Expression(expr body)

    -- not really an actual node but useful in Jython's typesystem.
    | Suite(stmt* body)

    stmt = FunctionDef(identifier name, arguments args,
                       stmt* body, expr* decorator_list)
        | ClassDef(identifier name, expr* bases, stmt* body, expr* decorator_list)
```

```

| Return(expr? value)

| Delete(expr* targets)
| Assign(expr* targets, expr value)
| AugAssign(expr target, operator op, expr value)

-- not sure if bool is allowed, can always use int
| Print(expr? dest, expr* values, bool nl)

-- use 'orelse' because else is a keyword in target languages
| For(expr target, expr iter, stmt* body, stmt* orelse)
| While(expr test, stmt* body, stmt* orelse)
| If(expr test, stmt* body, stmt* orelse)
| With(expr context_expr, expr? optional_vars, stmt* body)

-- 'type' is a bad name
| Raise(expr? type, expr? inst, expr? tback)
| TryExcept(stmt* body, excepthandler* handlers, stmt* orelse)
| TryFinally(stmt* body, stmt* finalbody)
| Assert(expr test, expr? msg)

| Import(alias* names)
| ImportFrom(identifier? module, alias* names, int? level)

-- Doesn't capture requirement that locals must be
-- defined if globals is
-- still supports use as a function!
| Exec(expr body, expr? globals, expr? locals)

| Global(identifier* names)
| Expr(expr value)
| Pass | Break | Continue

-- XXX Jython will be different
-- col_offset is the byte offset in the utf8 string the parser uses
attributes (int lineno, int col_offset)

-- BoolOp() can use left & right?
expr = BoolOp(boolop op, expr* values)
| BinOp(expr left, operator op, expr right)
| UnaryOp(unaryop op, expr operand)
| Lambda(arguments args, expr body)
| IfExp(expr test, expr body, expr orelse)
| Dict(expr* keys, expr* values)
| Set(expr* elts)
| ListComp(expr elt, comprehension* generators)
| SetComp(expr elt, comprehension* generators)
| DictComp(expr key, expr value, comprehension* generators)
| GeneratorExp(expr elt, comprehension* generators)
-- the grammar constrains where yield expressions can occur
| Yield(expr? value)
-- need sequences for compare to distinguish between
-- x < 4 < 3 and (x < 4) < 3
| Compare(expr left, cmpop* ops, expr* comparators)

```

```

    | Call(expr func, expr* args, keyword* keywords,
          expr? starargs, expr? kwargs)
    | Repr(expr value)
    | Num(object n) -- a number as a PyObject.
    | Str(string s) -- need to specify raw, unicode, etc?
-- other literals? bools?

-- the following expression can appear in assignment context
| Attribute(expr value, identifier attr, expr_context ctx)
| Subscript(expr value, slice slice, expr_context ctx)
| Name(identifier id, expr_context ctx)
| List(expr* elts, expr_context ctx)
| Tuple(expr* elts, expr_context ctx)

-- col_offset is the byte offset in the utf8 string the parser uses
attributes (int lineno, int col_offset)

expr_context = Load | Store | Del | AugLoad | AugStore | Param

slice = Ellipsis | Slice(expr? lower, expr? upper, expr? step)
       | ExtSlice(slice* dims)
       | Index(expr value)

boolop = And | Or

operator = Add | Sub | Mult | Div | Mod | Pow | LShift
          | RShift | BitOr | BitXor | BitAnd | FloorDiv

unaryop = Invert | Not | UAdd | USub

cmpop = Eq | NotEq | Lt | LtE | Gt | GtE | Is | IsNot | In | NotIn

comprehension = (expr target, expr iter, expr* ifs)

-- not sure what to call the first argument for raise and except
except_handler = ExceptHandler(expr? type, expr? name, stmt* body)
               attributes (int lineno, int col_offset)

arguments = (expr* args, identifier? vararg,
            identifier? kwarg, expr* defaults)

-- keyword arguments supplied to call
keyword = (identifier arg, expr value)

-- import name with optional 'as' alias.
alias = (identifier name, identifier? asname)
}

```

### 31.2.3 ast Helpers

New in version 2.6. Apart from the node classes, `ast` module defines these utility functions and classes for traversing abstract syntax trees:

`ast.parse` (*source*, *filename*='<unknown>', *mode*='exec')

Parse the source into an AST node. Equivalent to `compile(source, filename, mode, ast.PyCF_ONLY_AST)`.

`ast.literal_eval(node_or_string)`

Safely evaluate an expression node or a string containing a Python expression. The string or node provided may only consist of the following Python literal structures: strings, numbers, tuples, lists, dicts, booleans, and `None`.

This can be used for safely evaluating strings containing Python expressions from untrusted sources without the need to parse the values oneself.

`ast.get_docstring(node, clean=True)`

Return the docstring of the given *node* (which must be a `FunctionDef`, `ClassDef` or `Module` node), or `None` if it has no docstring. If *clean* is true, clean up the docstring's indentation with `inspect.cleandoc()`.

`ast.fix_missing_locations(node)`

When you compile a node tree with `compile()`, the compiler expects `lineno` and `col_offset` attributes for every node that supports them. This is rather tedious to fill in for generated nodes, so this helper adds these attributes recursively where not already set, by setting them to the values of the parent node. It works recursively starting at *node*.

`ast.increment_lineno(node, n=1)`

Increment the line number of each node in the tree starting at *node* by *n*. This is useful to “move code” to a different location in a file.

`ast.copy_location(new_node, old_node)`

Copy source location (`lineno` and `col_offset`) from *old\_node* to *new\_node* if possible, and return *new\_node*.

`ast.iter_fields(node)`

Yield a tuple of (*fieldname*, *value*) for each field in `node._fields` that is present on *node*.

`ast.iter_child_nodes(node)`

Yield all direct child nodes of *node*, that is, all fields that are nodes and all items of fields that are lists of nodes.

`ast.walk(node)`

Recursively yield all descendant nodes in the tree starting at *node* (including *node* itself), in no specified order. This is useful if you only want to modify nodes in place and don't care about the context.

**class** `ast.NodeVisitor`

A node visitor base class that walks the abstract syntax tree and calls a visitor function for every node found. This function may return a value which is forwarded by the `visit()` method.

This class is meant to be subclassed, with the subclass adding visitor methods.

**visit** (*node*)

Visit a node. The default implementation calls the method called `'self.visit_classname'` where *classname* is the name of the node class, or `generic_visit()` if that method doesn't exist.

**generic\_visit** (*node*)

This visitor calls `visit()` on all children of the node.

Note that child nodes of nodes that have a custom visitor method won't be visited unless the visitor calls `generic_visit()` or visits them itself.

Don't use the `NodeVisitor` if you want to apply changes to nodes during traversal. For this a special visitor exists (`NodeTransformer`) that allows modifications.

**class** `ast.NodeTransformer`

A `NodeVisitor` subclass that walks the abstract syntax tree and allows modification of nodes.

The `NodeTransformer` will walk the AST and use the return value of the visitor methods to replace or remove the old node. If the return value of the visitor method is `None`, the node will be removed from its

location, otherwise it is replaced with the return value. The return value may be the original node in which case no replacement takes place.

Here is an example transformer that rewrites all occurrences of name lookups (`foo`) to `data['foo']`:

```
class RewriteName(NodeTransformer):

    def visit_Name(self, node):
        return copy_location(Subscript(
            value=Name(id='data', ctx=Load()),
            slice=Index(value=Str(s=node.id)),
            ctx=node.ctx
        ), node)
```

Keep in mind that if the node you're operating on has child nodes you must either transform the child nodes yourself or call the `generic_visit()` method for the node first.

For nodes that were part of a collection of statements (that applies to all statement nodes), the visitor may also return a list of nodes rather than just a single node.

Usually you use the transformer like this:

```
node = YourTransformer().visit(node)
```

`ast.dump(node, annotate_fields=True, include_attributes=False)`

Return a formatted dump of the tree in `node`. This is mainly useful for debugging purposes. The returned string will show the names and the values for fields. This makes the code impossible to evaluate, so if evaluation is wanted `annotate_fields` must be set to `False`. Attributes such as line numbers and column offsets are not dumped by default. If this is wanted, `include_attributes` can be set to `True`.

## 31.3 `symtable` — Access to the compiler's symbol tables

Symbol tables are generated by the compiler from AST just before bytecode is generated. The symbol table is responsible for calculating the scope of every identifier in the code. `symtable` provides an interface to examine these tables.

### 31.3.1 Generating Symbol Tables

`symtable.symtable(code, filename, compile_type)`

Return the toplevel `SymbolTable` for the Python source `code`. `filename` is the name of the file containing the code. `compile_type` is like the `mode` argument to `compile()`.

### 31.3.2 Examining Symbol Tables

`class symtable.SymbolTable`

A namespace table for a block. The constructor is not public.

`get_type()`

Return the type of the symbol table. Possible values are `'class'`, `'module'`, and `'function'`.

`get_id()`

Return the table's identifier.

**get\_name()**

Return the table's name. This is the name of the class if the table is for a class, the name of the function if the table is for a function, or 'top' if the table is global (`get_type()` returns 'module').

**get\_lineno()**

Return the number of the first line in the block this table represents.

**is\_optimized()**

Return True if the locals in this table can be optimized.

**is\_nested()**

Return True if the block is a nested class or function.

**has\_children()**

Return True if the block has nested namespaces within it. These can be obtained with `get_children()`.

**has\_exec()**

Return True if the block uses `exec`.

**has\_import\_star()**

Return True if the block uses a starred from-import.

**get\_identifiers()**

Return a list of names of symbols in this table.

**lookup(name)**

Lookup *name* in the table and return a `Symbol` instance.

**get\_symbols()**

Return a list of `Symbol` instances for names in the table.

**get\_children()**

Return a list of the nested symbol tables.

**class** `symtable.Function`

A namespace for a function or method. This class inherits `SymbolTable`.

**get\_parameters()**

Return a tuple containing names of parameters to this function.

**get\_locals()**

Return a tuple containing names of locals in this function.

**get\_globals()**

Return a tuple containing names of globals in this function.

**get\_frees()**

Return a tuple containing names of free variables in this function.

**class** `symtable.Class`

A namespace of a class. This class inherits `SymbolTable`.

**get\_methods()**

Return a tuple containing the names of methods declared in the class.

**class** `symtable.Symbol`

An entry in a `SymbolTable` corresponding to an identifier in the source. The constructor is not public.

**get\_name()**

Return the symbol's name.

**is\_referenced()**

Return True if the symbol is used in its block.

**is\_imported()**

Return True if the symbol is created from an import statement.

**is\_parameter()**

Return True if the symbol is a parameter.

**is\_global()**

Return True if the symbol is global.

**is\_declared\_global()**

Return True if the symbol is declared global with a global statement.

**is\_local()**

Return True if the symbol is local to its block.

**is\_free()**

Return True if the symbol is referenced in its block, but not assigned to.

**is\_assigned()**

Return True if the symbol is assigned to in its block.

**is\_namespace()**

Return True if name binding introduces new namespace.

If the name is used as the target of a function or class statement, this will be true.

For example:

```
>>> table = symtable.symtable("def some_func(): pass", "string", "exec")
>>> table.lookup("some_func").is_namespace()
True
```

Note that a single name can be bound to multiple objects. If the result is True, the name may also be bound to other objects, like an int or list, that does not introduce a new namespace.

**get\_namespaces()**

Return a list of namespaces bound to this name.

**get\_namespace()**

Return the namespace bound to this name. If more than one namespace is bound, a `ValueError` is raised.

## 31.4 `symbol` — Constants used with Python parse trees

Source code: [Lib/symbol.py](#)

---

This module provides constants which represent the numeric values of internal nodes of the parse tree. Unlike most Python constants, these use lower-case names. Refer to the file `Grammar/Grammar` in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

This module also provides one additional data object:

`symbol.sym_name`

Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.

## 31.5 token — Constants used with Python parse trees

**Source code:** `Lib/token.py`

This module provides constants which represent the numeric values of leaf nodes of the parse tree (terminal tokens). Refer to the file `Grammar/Grammar` in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

The module also provides a mapping from numeric codes to names and some functions. The functions mirror definitions in the Python C header files.

`token.tok_name`

Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.

`token.ISTERMINAL(x)`

Return true for terminal token values.

`token.ISNONTERMINAL(x)`

Return true for non-terminal token values.

`token.ISEOF(x)`

Return true if `x` is the marker indicating the end of input.

The token constants are:

`token.ENDMARKER`

`token.NAME`

`token.NUMBER`

`token.STRING`

`token.NEWLINE`

`token.INDENT`

`token.DEDENT`

`token.LPAR`

`token.RPAR`

`token.LSQB`

`token.RSQB`

`token.COLON`

`token.COMMA`

`token.SEMI`

`token.PLUS`

`token.MINUS`

`token.STAR`

`token.SLASH`

`token.VBAR`

`token.AMPER`

`token.LESS`

`token.GREATER`

`token.EQUAL`

`token.DOT`

`token.PERCENT`

`token.BACKQUOTE`

`token.LBRACE`

`token.RBRACE`

`token.EQEQUAL`

`token.NOTEQUAL`

`token.LESSEQUAL`  
`token.GREATEREQUAL`  
`token.TILDE`  
`token.CIRCUMFLEX`  
`token.LEFTSHIFT`  
`token.RIGHTSHIFT`  
`token.DOUBLESTAR`  
`token.PLUSEQUAL`  
`token.MINEQUAL`  
`token.STAREQUAL`  
`token.SLASHEQUAL`  
`token.PERCENTEQUAL`  
`token.AMPEREQUAL`  
`token.VBAREQUAL`  
`token.CIRCUMFLEXEQUAL`  
`token.LEFTSHIFTEQUAL`  
`token.RIGHTSHIFTEQUAL`  
`token.DOUBLESTAREQUAL`  
`token.DOUBLESLASH`  
`token.DOUBLESLASHEQUAL`  
`token.AT`  
`token.OP`  
`token.ERRORTOKEN`  
`token.N_TOKENS`  
`token.NT_OFFSET`

**See Also:**

**Module `parser`** The second example for the `parser` module shows how to use the `symbol` module.

## 31.6 `keyword` — Testing for Python keywords

**Source code:** [Lib/keyword.py](#)

---

This module allows a Python program to determine if a string is a keyword.

`keyword.iskeyword(s)`

Return true if *s* is a Python keyword.

`keyword.kwlist`

Sequence containing all the keywords defined for the interpreter. If any keywords are defined to only be active when particular `__future__` statements are in effect, these will be included as well.

## 31.7 `tokenize` — Tokenizer for Python source

**Source code:** [Lib/tokenize.py](#)

---

The `tokenize` module provides a lexical scanner for Python source code, implemented in Python. The scanner in this module returns comments as tokens as well, making it useful for implementing “pretty-printers,” including colorizers for on-screen displays.

To simplify token stream handling, all *operators* and *delimiters* tokens are returned using the generic `token.OP` token type. The exact type can be determined by checking the token `string` field on the *named tuple* returned from `tokenize.tokenize()` for the character sequence that identifies a specific operator token.

The primary entry point is a *generator*:

```
tokenize.generate_tokens(readline)
```

The `generate_tokens()` generator requires one argument, *readline*, which must be a callable object which provides the same interface as the `readline()` method of built-in file objects (see section *File Objects*). Each call to the function should return one line of input as a string. Alternately, *readline* may be a callable object that signals completion by raising `StopIteration`.

The generator produces 5-tuples with these members: the token type; the token string; a 2-tuple (`srow`, `scol`) of ints specifying the row and column where the token begins in the source; a 2-tuple (`erow`, `ecol`) of ints specifying the row and column where the token ends in the source; and the line on which the token was found. The line passed (the last tuple item) is the *logical* line; continuation lines are included. New in version 2.2.

An older entry point is retained for backward compatibility:

```
tokenize.tokenize(readline[, tokeneater])
```

The `tokenize()` function accepts two parameters: one representing the input stream, and one providing an output mechanism for `tokenize()`.

The first parameter, *readline*, must be a callable object which provides the same interface as the `readline()` method of built-in file objects (see section *File Objects*). Each call to the function should return one line of input as a string. Alternately, *readline* may be a callable object that signals completion by raising `StopIteration`. Changed in version 2.5: Added `StopIteration` support. The second parameter, *tokeneater*, must also be a callable object. It is called once for each token, with five arguments, corresponding to the tuples generated by `generate_tokens()`.

All constants from the `token` module are also exported from `tokenize`, as are two additional token type values that might be passed to the *tokeneater* function by `tokenize()`:

```
tokenize.COMMENT
```

Token value used to indicate a comment.

```
tokenize.NL
```

Token value used to indicate a non-terminating newline. The `NEWLINE` token indicates the end of a logical line of Python code; `NL` tokens are generated when a logical line of code is continued over multiple physical lines.

Another function is provided to reverse the tokenization process. This is useful for creating tools that tokenize a script, modify the token stream, and write back the modified script.

```
tokenize.untokenize(iterable)
```

Converts tokens back into Python source code. The *iterable* must return sequences with at least two elements, the token type and the token string. Any additional sequence elements are ignored.

The reconstructed script is returned as a single string. The result is guaranteed to tokenize back to match the input so that the conversion is lossless and round-trips are assured. The guarantee applies only to the token type and token string as the spacing between tokens (column positions) may change. New in version 2.5.

Example of a script re-writer that transforms float literals into `Decimal` objects:

```
def decistmt(s):
    """Substitute Decimals for floats in a string of statements.

    >>> from decimal import Decimal
    >>> s = 'print +21.3e-5*-.1234/81.7'
    >>> decistmt(s)
```

```
"print +Decimal ('21.3e-5')*-Decimal ('.1234')/Decimal ('81.7')"  
  
>>> exec(s)  
-3.21716034272e-007  
>>> exec(decistmt(s))  
-3.217160342717258261933904529E-7  
  
"""  
result = []  
g = generate_tokens(StringIO(s).readline) # tokenize the string  
for toknum, tokval, _, _, _ in g:  
    if toknum == NUMBER and '.' in tokval: # replace NUMBER tokens  
        result.extend([  
            (NAME, 'Decimal'),  
            (OP, '('),  
            (STRING, repr(tokval)),  
            (OP, ')')  
        ])  
    else:  
        result.append((toknum, tokval))  
return untokenize(result)
```

## 31.8 tabnanny — Detection of ambiguous indentation

**Source code:** [Lib/tabnanny.py](#)

---

For the time being this module is intended to be called as a script. However it is possible to import it into an IDE and use the function `check()` described below.

---

**Note:** The API provided by this module is likely to change in future releases; such changes may not be backward compatible.

---

`tabnanny.check(file_or_dir)`

If `file_or_dir` is a directory and not a symbolic link, then recursively descend the directory tree named by `file_or_dir`, checking all `.py` files along the way. If `file_or_dir` is an ordinary Python source file, it is checked for whitespace related problems. The diagnostic messages are written to standard output using the print statement.

`tabnanny.verbose`

Flag indicating whether to print verbose messages. This is incremented by the `-v` option if called as a script.

`tabnanny.filename_only`

Flag indicating whether to print only the filenames of files containing whitespace related problems. This is set to true by the `-q` option if called as a script.

**exception** `tabnanny.NannyNag`

Raised by `tokeneater()` if detecting an ambiguous indent. Captured and handled in `check()`.

`tabnanny.tokeneater(type, token, start, end, line)`

This function is used by `check()` as a callback parameter to the function `tokenize.tokenize()`.

**See Also:**

**Module** `tokenize` Lexical scanner for Python source code.

## 31.9 pyc1br — Python class browser support

**Source code:** [Lib/pyc1br.py](#)

The `pyc1br` module can be used to determine some limited information about the classes, methods and top-level functions defined in a module. The information provided is sufficient to implement a traditional three-pane class browser. The information is extracted from the source code rather than by importing the module, so this module is safe to use with untrusted code. This restriction makes it impossible to use this module with modules not implemented in Python, including all standard and optional extension modules.

`pyc1br.readmodule` (*module*, *path=None*)

Read a module and return a dictionary mapping class names to class descriptor objects. The parameter *module* should be the name of a module as a string; it may be the name of a module within a package. The *path* parameter should be a sequence, and is used to augment the value of `sys.path`, which is used to locate module source code.

`pyc1br.readmodule_ex` (*module*, *path=None*)

Like `readmodule()`, but the returned dictionary, in addition to mapping class names to class descriptor objects, also maps top-level function names to function descriptor objects. Moreover, if the module being read is a package, the key `'__path__'` in the returned dictionary has as its value a list which contains the package search path.

### 31.9.1 Class Objects

The `Class` objects used as values in the dictionary returned by `readmodule()` and `readmodule_ex()` provide the following data attributes:

**Class.module**

The name of the module defining the class described by the class descriptor.

**Class.name**

The name of the class.

**Class.super**

A list of `Class` objects which describe the immediate base classes of the class being described. Classes which are named as superclasses but which are not discoverable by `readmodule()` are listed as a string with the class name instead of as `Class` objects.

**Class.methods**

A dictionary mapping method names to line numbers.

**Class.file**

Name of the file containing the `class` statement defining the class.

**Class.lineno**

The line number of the `class` statement within the file named by `file`.

### 31.9.2 Function Objects

The `Function` objects used as values in the dictionary returned by `readmodule_ex()` provide the following attributes:

**Function.module**

The name of the module defining the function described by the function descriptor.

`Function.name`

The name of the function.

`Function.file`

Name of the file containing the `def` statement defining the function.

`Function.lineno`

The line number of the `def` statement within the file named by `file`.

## 31.10 `py_compile` — Compile Python source files

**Source code:** `Lib/py_compile.py`

---

The `py_compile` module provides a function to generate a byte-code file from a source file, and another function used when the module source file is invoked as a script.

Though not often needed, this function can be useful when installing modules for shared use, especially if some of the users may not have permission to write the byte-code cache files in the directory containing the source code.

**exception `py_compile.PyCompileError`**

Exception raised when an error occurs while attempting to compile the file.

`py_compile.compile(file[, cfile[, dfile[, doraise ] ]])`

Compile a source file to byte-code and write out the byte-code cache file. The source code is loaded from the file name `file`. The byte-code is written to `cfile`, which defaults to `file + 'c'` ('o' if optimization is enabled in the current interpreter). If `dfile` is specified, it is used as the name of the source file in error messages instead of `file`. If `doraise` is true, a `PyCompileError` is raised when an error is encountered while compiling `file`. If `doraise` is false (the default), an error string is written to `sys.stderr`, but no exception is raised.

`py_compile.main([args])`

Compile several source files. The files named in `args` (or on the command line, if `args` is not specified) are compiled and the resulting bytecode is cached in the normal manner. This function does not search a directory structure to locate source files; it only compiles files named explicitly. If `'-'` is the only parameter in `args`, the list of files is taken from standard input. Changed in version 2.7: Added support for `'-'`.

When this module is run as a script, the `main()` is used to compile all the files named on the command line. The exit status is nonzero if one of the files could not be compiled. Changed in version 2.6: Added the nonzero exit status when module is run as a script.

**See Also:**

**Module `compileall`** Utilities to compile all Python source files in a directory tree.

## 31.11 `compileall` — Byte-compile Python libraries

This module provides some utility functions to support installing Python libraries. These functions compile Python source files in a directory tree. This module can be used to create the cached byte-code files at library installation time, which makes them available for use even by users who don't have write permission to the library directories.

### 31.11.1 Command-line use

This module can work as a script (using `python -m compileall`) to compile Python sources.

**[directory|file]...**

Positional arguments are files to compile or directories that contain source files, traversed recursively. If no argument is given, behave as if the command line was `-l <directories from sys.path>`.

**-l**

Do not recurse into subdirectories, only compile source code files directly contained in the named or implied directories.

**-f**

Force rebuild even if timestamps are up-to-date.

**-q**

Do not print the list of files compiled, print only error messages.

**-d** *destdir*

Directory prepended to the path to each file being compiled. This will appear in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

**-x** *regex*

*regex* is used to search the full path to each file considered for compilation, and if the regex produces a match, the file is skipped.

**-i** *list*

Read the file *list* and add each line that it contains to the list of files and directories to compile. If *list* is `-`, read lines from `stdin`.

Changed in version 2.7: Added the `-i` option.

### 31.11.2 Public functions

`compileall.compile_dir` (*dir*[, *maxlevels*[, *ddir*[, *force*[, *rx*[, *quiet*]]]]])

Recursively descend the directory tree named by *dir*, compiling all `.py` files along the way.

The *maxlevels* parameter is used to limit the depth of the recursion; it defaults to 10.

If *ddir* is given, it is prepended to the path to each file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If *force* is true, modules are re-compiled even if the timestamps are up to date.

If *rx* is given, its search method is called on the complete path to each file considered for compilation, and if it returns a true value, the file is skipped.

If *quiet* is true, nothing is printed to the standard output unless errors occur.

`compileall.compile_file` (*fullname*[, *ddir*[, *force*[, *rx*[, *quiet*]]]]])

Compile the file with path *fullname*.

If *ddir* is given, it is prepended to the path to the file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If *rx* is given, its search method is passed the full path name to the file being compiled, and if it returns a true value, the file is not compiled and `True` is returned.

If *quiet* is true, nothing is printed to the standard output unless errors occur. New in version 2.7.

`compileall.compile_path` ([*skip\_curdir*[, *maxlevels*[, *force*]]])

Byte-compile all the `.py` files found along `sys.path`. If *skip\_curdir* is true (the default), the current directory

is not included in the search. All other parameters are passed to the `compile_dir()` function. Note that unlike the other compile functions, `maxlevels` defaults to 0.

To force a recompile of all the `.py` files in the `Lib/` subdirectory and all its subdirectories:

```
import compileall
```

```
compileall.compile_dir('Lib/', force=True)
```

```
# Perform same compilation, excluding files in .svn directories.
```

```
import re
```

```
compileall.compile_dir('Lib/', rx=re.compile('[.]svn'), force=True)
```

**See Also:**

**Module `py_compile`** Byte-compile a single source file.

## 31.12 `dis` — Disassembler for Python bytecode

**Source code:** `Lib/dis.py`

---

The `dis` module supports the analysis of CPython *bytecode* by disassembling it. The CPython bytecode which this module takes as an input is defined in the file `Include/opcode.h` and used by the compiler and the interpreter.

**CPython implementation detail:** Bytecode is an implementation detail of the CPython interpreter! No guarantees are made that bytecode will not be added, removed, or changed between versions of Python. Use of this module should not be considered to work across Python VMs or Python releases.

Example: Given the function `myfunc()`:

```
def myfunc(alist):
    return len(alist)
```

the following command can be used to get the disassembly of `myfunc()`:

```
>>> dis.dis(myfunc)
2           0 LOAD_GLOBAL           0 (len)
           3 LOAD_FAST             0 (alist)
           6 CALL_FUNCTION         1
           9 RETURN_VALUE
```

(The “2” is a line number).

The `dis` module defines the following functions and constants:

`dis.dis([bytesource])`

Disassemble the *bytesource* object. *bytesource* can denote either a module, a class, a method, a function, or a code object. For a module, it disassembles all functions. For a class, it disassembles all methods. For a single code sequence, it prints one line per bytecode instruction. If no object is provided, it disassembles the last traceback.

`dis.distb([tb])`

Disassembles the top-of-stack function of a traceback, using the last traceback if none was passed. The instruction causing the exception is indicated.

`dis.disassemble(code[, lasti])`

Disassembles a code object, indicating the last instruction if *lasti* was provided. The output is divided in the following columns:

- 1.the line number, for the first instruction of each line
- 2.the current instruction, indicated as -->,
- 3.a labelled instruction, indicated with >>,
- 4.the address of the instruction,
- 5.the operation code name,
- 6.operation parameters, and
- 7.interpretation of the parameters in parentheses.

The parameter interpretation recognizes local and global variable names, constant values, branch targets, and compare operators.

`dis.disco` (*code*[, *lasti* ])

A synonym for `disassemble()`. It is more convenient to type, and kept for compatibility with earlier Python releases.

`dis.findlinestarts` (*code*)

This generator function uses the `co_firstlineno` and `co_lnotab` attributes of the code object *code* to find the offsets which are starts of lines in the source code. They are generated as (*offset*, *lineno*) pairs.

`dis.findlabels` (*code*)

Detect all offsets in the code object *code* which are jump targets, and return a list of these offsets.

`dis.opname`

Sequence of operation names, indexable using the bytecode.

`dis.opmap`

Dictionary mapping operation names to bytecodes.

`dis.cmp_op`

Sequence of all compare operation names.

`dis.hasconst`

Sequence of bytecodes that have a constant parameter.

`dis.hasfree`

Sequence of bytecodes that access a free variable.

`dis.hasname`

Sequence of bytecodes that access an attribute by name.

`dis.hasjrel`

Sequence of bytecodes that have a relative jump target.

`dis.hasjabs`

Sequence of bytecodes that have an absolute jump target.

`dis.haslocal`

Sequence of bytecodes that access a local variable.

`dis.hascompare`

Sequence of bytecodes of Boolean operations.

### 31.12.1 Python Bytecode Instructions

The Python compiler currently generates the following bytecode instructions.

`STOP_CODE` ()

Indicates end-of-code to the compiler, not used by the interpreter.

**NOP ()**

Do nothing code. Used as a placeholder by the bytecode optimizer.

**POP\_TOP ()**

Removes the top-of-stack (TOS) item.

**ROT\_TWO ()**

Swaps the two top-most stack items.

**ROT\_THREE ()**

Lifts second and third stack item one position up, moves top down to position three.

**ROT\_FOUR ()**

Lifts second, third and fourth stack item one position up, moves top down to position four.

**DUP\_TOP ()**

Duplicates the reference on top of the stack.

Unary Operations take the top of the stack, apply the operation, and push the result back on the stack.

**UNARY\_POSITIVE ()**

Implements `TOS = +TOS`.

**UNARY\_NEGATIVE ()**

Implements `TOS = -TOS`.

**UNARY\_NOT ()**

Implements `TOS = not TOS`.

**UNARY\_CONVERT ()**

Implements `TOS = `TOS``.

**UNARY\_INVERT ()**

Implements `TOS = ~TOS`.

**GET\_ITER ()**

Implements `TOS = iter(TOS)`.

Binary operations remove the top of the stack (TOS) and the second top-most stack item (TOS1) from the stack. They perform the operation, and put the result back on the stack.

**BINARY\_POWER ()**

Implements `TOS = TOS1 ** TOS`.

**BINARY\_MULTIPLY ()**

Implements `TOS = TOS1 * TOS`.

**BINARY\_DIVIDE ()**

Implements `TOS = TOS1 / TOS` when `from __future__ import division` is not in effect.

**BINARY\_FLOOR\_DIVIDE ()**

Implements `TOS = TOS1 // TOS`.

**BINARY\_TRUE\_DIVIDE ()**

Implements `TOS = TOS1 / TOS` when `from __future__ import division` is in effect.

**BINARY\_MODULO ()**

Implements `TOS = TOS1 % TOS`.

**BINARY\_ADD ()**

Implements `TOS = TOS1 + TOS`.

**BINARY\_SUBTRACT ()**

Implements `TOS = TOS1 - TOS`.

**BINARY\_SUBSCR()**

Implements `TOS = TOS1[TOS]`.

**BINARY\_LSHIFT()**

Implements `TOS = TOS1 << TOS`.

**BINARY\_RSHIFT()**

Implements `TOS = TOS1 >> TOS`.

**BINARY\_AND()**

Implements `TOS = TOS1 & TOS`.

**BINARY\_XOR()**

Implements `TOS = TOS1 ^ TOS`.

**BINARY\_OR()**

Implements `TOS = TOS1 | TOS`.

In-place operations are like binary operations, in that they remove TOS and TOS1, and push the result back on the stack, but the operation is done in-place when TOS1 supports it, and the resulting TOS may be (but does not have to be) the original TOS1.

**INPLACE\_POWER()**

Implements in-place `TOS = TOS1 ** TOS`.

**INPLACE\_MULTIPLY()**

Implements in-place `TOS = TOS1 * TOS`.

**INPLACE\_DIVIDE()**

Implements in-place `TOS = TOS1 / TOS` when from `__future__` import `division` is not in effect.

**INPLACE\_FLOOR\_DIVIDE()**

Implements in-place `TOS = TOS1 // TOS`.

**INPLACE\_TRUE\_DIVIDE()**

Implements in-place `TOS = TOS1 / TOS` when from `__future__` import `division` is in effect.

**INPLACE\_MODULO()**

Implements in-place `TOS = TOS1 % TOS`.

**INPLACE\_ADD()**

Implements in-place `TOS = TOS1 + TOS`.

**INPLACE\_SUBTRACT()**

Implements in-place `TOS = TOS1 - TOS`.

**INPLACE\_LSHIFT()**

Implements in-place `TOS = TOS1 << TOS`.

**INPLACE\_RSHIFT()**

Implements in-place `TOS = TOS1 >> TOS`.

**INPLACE\_AND()**

Implements in-place `TOS = TOS1 & TOS`.

**INPLACE\_XOR()**

Implements in-place `TOS = TOS1 ^ TOS`.

**INPLACE\_OR()**

Implements in-place `TOS = TOS1 | TOS`.

The slice opcodes take up to three parameters.

**SLICE+0()**

Implements `TOS = TOS[:]`.

**SLICE+1()**

Implements `TOS = TOS1[TOS:]`.

**SLICE+2()**

Implements `TOS = TOS1[:TOS]`.

**SLICE+3()**

Implements `TOS = TOS2[TOS1:TOS]`.

Slice assignment needs even an additional parameter. As any statement, they put nothing on the stack.

**STORE\_SLICE+0()**

Implements `TOS[:] = TOS1`.

**STORE\_SLICE+1()**

Implements `TOS1[TOS:] = TOS2`.

**STORE\_SLICE+2()**

Implements `TOS1[:TOS] = TOS2`.

**STORE\_SLICE+3()**

Implements `TOS2[TOS1:TOS] = TOS3`.

**DELETE\_SLICE+0()**

Implements `del TOS[:]`.

**DELETE\_SLICE+1()**

Implements `del TOS1[TOS:]`.

**DELETE\_SLICE+2()**

Implements `del TOS1[:TOS]`.

**DELETE\_SLICE+3()**

Implements `del TOS2[TOS1:TOS]`.

**STORE\_SUBSCR()**

Implements `TOS1[TOS] = TOS2`.

**DELETE\_SUBSCR()**

Implements `del TOS1[TOS]`.

Miscellaneous opcodes.

**PRINT\_EXPR()**

Implements the expression statement for the interactive mode. TOS is removed from the stack and printed. In non-interactive mode, an expression statement is terminated with `POP_STACK`.

**PRINT\_ITEM()**

Prints TOS to the file-like object bound to `sys.stdout`. There is one such instruction for each item in the `print` statement.

**PRINT\_ITEM\_TO()**

Like `PRINT_ITEM`, but prints the item second from TOS to the file-like object at TOS. This is used by the extended `print` statement.

**PRINT\_NEWLINE()**

Prints a new line on `sys.stdout`. This is generated as the last operation of a `print` statement, unless the statement ends with a comma.

**PRINT\_NEWLINE\_TO ()**

Like `PRINT_NEWLINE`, but prints the new line on the file-like object on the TOS. This is used by the extended print statement.

**BREAK\_LOOP ()**

Terminates a loop due to a `break` statement.

**CONTINUE\_LOOP (*target*)**

Continues a loop due to a `continue` statement. *target* is the address to jump to (which should be a `FOR_ITER` instruction).

**LIST\_APPEND (*i*)**

Calls `list.append(TOS[-i], TOS)`. Used to implement list comprehensions. While the appended value is popped off, the list object remains on the stack so that it is available for further iterations of the loop.

**LOAD\_LOCALS ()**

Pushes a reference to the locals of the current scope on the stack. This is used in the code for a class definition: After the class body is evaluated, the locals are passed to the class definition.

**RETURN\_VALUE ()**

Returns with TOS to the caller of the function.

**YIELD\_VALUE ()**

Pops TOS and yields it from a *generator*.

**IMPORT\_STAR ()**

Loads all symbols not starting with `'_'` directly from the module TOS to the local namespace. The module is popped after loading all names. This opcode implements `from module import *`.

**EXEC\_STMT ()**

Implements `exec TOS2, TOS1, TOS`. The compiler fills missing optional parameters with `None`.

**POP\_BLOCK ()**

Removes one block from the block stack. Per frame, there is a stack of blocks, denoting nested loops, try statements, and such.

**END\_FINALLY ()**

Terminates a `finally` clause. The interpreter recalls whether the exception has to be re-raised, or whether the function returns, and continues with the outer-next block.

**BUILD\_CLASS ()**

Creates a new class object. TOS is the methods dictionary, TOS1 the tuple of the names of the base classes, and TOS2 the class name.

**SETUP\_WITH (*delta*)**

This opcode performs several operations before a `with` block starts. First, it loads `__exit__()` from the context manager and pushes it onto the stack for later use by `WITH_CLEANUP`. Then, `__enter__()` is called, and a finally block pointing to *delta* is pushed. Finally, the result of calling the enter method is pushed onto the stack. The next opcode will either ignore it (`POP_TOP`), or store it in (a) variable(s) (`STORE_FAST`, `STORE_NAME`, or `UNPACK_SEQUENCE`).

**WITH\_CLEANUP ()**

Cleans up the stack when a `with` statement block exits. On top of the stack are 1–3 values indicating how/why the finally clause was entered:

- TOP = `None`
- (TOP, SECOND) = (`WHY_{RETURN, CONTINUE}`), `retval`
- TOP = `WHY_*`; no `retval` below it
- (TOP, SECOND, THIRD) = `exc_info()`

Under them is EXIT, the context manager's `__exit__()` bound method.

In the last case, `EXIT(TOP, SECOND, THIRD)` is called, otherwise `EXIT(None, None, None)`.

EXIT is removed from the stack, leaving the values above it in the same order. In addition, if the stack represents an exception, *and* the function call returns a 'true' value, this information is "zapped", to prevent `END_FINALLY` from re-raising the exception. (But non-local gotos should still be resumed.)

All of the following opcodes expect arguments. An argument is two bytes, with the more significant byte last.

**STORE\_NAME** (*namei*)

Implements `name = TOS`. *namei* is the index of *name* in the attribute `co_names` of the code object. The compiler tries to use `STORE_FAST` or `STORE_GLOBAL` if possible.

**DELETE\_NAME** (*namei*)

Implements `del name`, where *namei* is the index into `co_names` attribute of the code object.

**UNPACK\_SEQUENCE** (*count*)

Unpacks TOS into *count* individual values, which are put onto the stack right-to-left.

**DUP\_TOPX** (*count*)

Duplicate *count* items, keeping them in the same order. Due to implementation limits, *count* should be between 1 and 5 inclusive.

**STORE\_ATTR** (*namei*)

Implements `TOS.name = TOS1`, where *namei* is the index of *name* in `co_names`.

**DELETE\_ATTR** (*namei*)

Implements `del TOS.name`, using *namei* as index into `co_names`.

**STORE\_GLOBAL** (*namei*)

Works as `STORE_NAME`, but stores the name as a global.

**DELETE\_GLOBAL** (*namei*)

Works as `DELETE_NAME`, but deletes a global name.

**LOAD\_CONST** (*consti*)

Pushes `co_consts[consti]` onto the stack.

**LOAD\_NAME** (*namei*)

Pushes the value associated with `co_names[namei]` onto the stack.

**BUILD\_TUPLE** (*count*)

Creates a tuple consuming *count* items from the stack, and pushes the resulting tuple onto the stack.

**BUILD\_LIST** (*count*)

Works as `BUILD_TUPLE`, but creates a list.

**BUILD\_MAP** (*count*)

Pushes a new dictionary object onto the stack. The dictionary is pre-sized to hold *count* entries.

**LOAD\_ATTR** (*namei*)

Replaces TOS with `getattr(TOS, co_names[namei])`.

**COMPARE\_OP** (*opname*)

Performs a Boolean operation. The operation name can be found in `cmp_op[opname]`.

**IMPORT\_NAME** (*namei*)

Imports the module `co_names[namei]`. TOS and TOS1 are popped and provide the *fromlist* and *level* arguments of `__import__()`. The module object is pushed onto the stack. The current namespace is not affected: for a `python import` statement, a subsequent `STORE_FAST` instruction modifies the namespace.

**IMPORT\_FROM** (*namei*)

Loads the attribute `co_names[namei]` from the module found in TOS. The resulting object is pushed onto the stack, to be subsequently stored by a `STORE_FAST` instruction.

**JUMP\_FORWARD** (*delta*)

Increments bytecode counter by *delta*.

**POP\_JUMP\_IF\_TRUE** (*target*)

If TOS is true, sets the bytecode counter to *target*. TOS is popped.

**POP\_JUMP\_IF\_FALSE** (*target*)

If TOS is false, sets the bytecode counter to *target*. TOS is popped.

**JUMP\_IF\_TRUE\_OR\_POP** (*target*)

If TOS is true, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is false), TOS is popped.

**JUMP\_IF\_FALSE\_OR\_POP** (*target*)

If TOS is false, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is true), TOS is popped.

**JUMP\_ABSOLUTE** (*target*)

Set bytecode counter to *target*.

**FOR\_ITER** (*delta*)

TOS is an *iterator*. Call its `next()` method. If this yields a new value, push it on the stack (leaving the iterator below it). If the iterator indicates it is exhausted TOS is popped, and the bytecode counter is incremented by *delta*.

**LOAD\_GLOBAL** (*namei*)

Loads the global named `co_names[namei]` onto the stack.

**SETUP\_LOOP** (*delta*)

Pushes a block for a loop onto the block stack. The block spans from the current instruction with a size of *delta* bytes.

**SETUP\_EXCEPT** (*delta*)

Pushes a try block from a try-except clause onto the block stack. *delta* points to the first except block.

**SETUP\_FINALLY** (*delta*)

Pushes a try block from a try-except clause onto the block stack. *delta* points to the finally block.

**STORE\_MAP** ()

Store a key and value pair in a dictionary. Pops the key and value while leaving the dictionary on the stack.

**LOAD\_FAST** (*var\_num*)

Pushes a reference to the local `co_varnames[var_num]` onto the stack.

**STORE\_FAST** (*var\_num*)

Stores TOS into the local `co_varnames[var_num]`.

**DELETE\_FAST** (*var\_num*)

Deletes local `co_varnames[var_num]`.

**LOAD\_CLOSURE** (*i*)

Pushes a reference to the cell contained in slot *i* of the cell and free variable storage. The name of the variable is `co_cellvars[i]` if *i* is less than the length of `co_cellvars`. Otherwise it is `co_freevars[i - len(co_cellvars)]`.

**LOAD\_DEREF** (*i*)

Loads the cell contained in slot *i* of the cell and free variable storage. Pushes a reference to the object the cell contains on the stack.

**STORE\_DEREF** (*i*)

Stores TOS into the cell contained in slot *i* of the cell and free variable storage.

**SET\_LINENO** (*lineno*)

This opcode is obsolete.

**RAISE\_VARARGS** (*argc*)

Raises an exception. *argc* indicates the number of parameters to the raise statement, ranging from 0 to 3. The handler will find the traceback as TOS2, the parameter as TOS1, and the exception as TOS.

**CALL\_FUNCTION** (*argc*)

Calls a function. The low byte of *argc* indicates the number of positional parameters, the high byte the number of keyword parameters. On the stack, the opcode finds the keyword parameters first. For each keyword argument, the value is on top of the key. Below the keyword parameters, the positional parameters are on the stack, with the right-most parameter on top. Below the parameters, the function object to call is on the stack. Pops all function arguments, and the function itself off the stack, and pushes the return value.

**MAKE\_FUNCTION** (*argc*)

Pushes a new function object on the stack. TOS is the code associated with the function. The function object is defined to have *argc* default parameters, which are found below TOS.

**MAKE\_CLOSURE** (*argc*)

Creates a new function object, sets its *func\_closure* slot, and pushes it on the stack. TOS is the code associated with the function, TOS1 the tuple containing cells for the closure's free variables. The function also has *argc* default parameters, which are found below the cells.

**BUILD\_SLICE** (*argc*)

Pushes a slice object on the stack. *argc* must be 2 or 3. If it is 2, `slice(TOS1, TOS)` is pushed; if it is 3, `slice(TOS2, TOS1, TOS)` is pushed. See the `slice()` built-in function for more information.

**EXTENDED\_ARG** (*ext*)

Prefixes any opcode which has an argument too big to fit into the default two bytes. *ext* holds two additional bytes which, taken together with the subsequent opcode's argument, comprise a four-byte argument, *ext* being the two most-significant bytes.

**CALL\_FUNCTION\_VAR** (*argc*)

Calls a function. *argc* is interpreted as in `CALL_FUNCTION`. The top element on the stack contains the variable argument list, followed by keyword and positional arguments.

**CALL\_FUNCTION\_KW** (*argc*)

Calls a function. *argc* is interpreted as in `CALL_FUNCTION`. The top element on the stack contains the keyword arguments dictionary, followed by explicit keyword and positional arguments.

**CALL\_FUNCTION\_VAR\_KW** (*argc*)

Calls a function. *argc* is interpreted as in `CALL_FUNCTION`. The top element on the stack contains the keyword arguments dictionary, followed by the variable-arguments tuple, followed by explicit keyword and positional arguments.

**HAVE\_ARGUMENT** ()

This is not really an opcode. It identifies the dividing line between opcodes which don't take arguments < HAVE\_ARGUMENT and those which do >= HAVE\_ARGUMENT.

## 31.13 pickletools — Tools for pickle developers

New in version 2.3. **Source code:** [Lib/pickletools.py](http://Lib/pickletools.py)

This module contains various constants relating to the intimate details of the `pickle` module, some lengthy comments about the implementation, and a few useful functions for analyzing pickled data. The contents of this module are useful for Python core developers who are working on the `pickle` and `cPickle` implementations; ordinary users of the `pickle` module probably won't find the `pickletools` module relevant.

`pickletools.dis` (*pickle*, *out=None*, *memo=None*, *indentlevel=4*)

Outputs a symbolic disassembly of the pickle to the file-like object *out*, defaulting to `sys.stdout`. *pickle* can be a string or a file-like object. *memo* can be a Python dictionary that will be used as the pickle's memo; it can be used to perform disassemblies across multiple pickles created by the same pickler. Successive levels, indicated by `MARK` opcodes in the stream, are indented by *indentlevel* spaces.

`pickletools.genops` (*pickle*)

Provides an *iterator* over all of the opcodes in a pickle, returning a sequence of (*opcode*, *arg*, *pos*) triples. *opcode* is an instance of an `OpcodeInfo` class; *arg* is the decoded value, as a Python object, of the opcode's argument; *pos* is the position at which this opcode is located. *pickle* can be a string or a file-like object.

`pickletools.optimize` (*picklestring*)

Returns a new equivalent pickle string after eliminating unused `PUT` opcodes. The optimized pickle is shorter, takes less transmission time, requires less storage space, and unpickles more efficiently. New in version 2.6.



# PYTHON COMPILER PACKAGE

Deprecated since version 2.6: The `compiler` package has been removed in Python 3. The Python compiler package is a tool for analyzing Python source code and generating Python bytecode. The compiler contains libraries to generate an abstract syntax tree from Python source code and to generate Python *bytecode* from the tree.

The `compiler` package is a Python source to bytecode translator written in Python. It uses the built-in parser and standard `parser` module to generate a concrete syntax tree. This tree is used to generate an abstract syntax tree (AST) and then Python bytecode.

The full functionality of the package duplicates the built-in compiler provided with the Python interpreter. It is intended to match its behavior almost exactly. Why implement another compiler that does the same thing? The package is useful for a variety of purposes. It can be modified more easily than the built-in compiler. The AST it generates is useful for analyzing Python source code.

This chapter explains how the various components of the `compiler` package work. It blends reference material with a tutorial.

## 32.1 The basic interface

The top-level of the package defines four functions. If you import `compiler`, you will get these functions and a collection of modules contained in the package.

`compiler.parse(buf)`

Returns an abstract syntax tree for the Python source code in *buf*. The function raises `SyntaxError` if there is an error in the source code. The return value is a `compiler.ast.Module` instance that contains the tree.

`compiler.parseFile(path)`

Return an abstract syntax tree for the Python source code in the file specified by *path*. It is equivalent to `parse(open(path).read())`.

`compiler.walk(ast, visitor[, verbose])`

Do a pre-order walk over the abstract syntax tree *ast*. Call the appropriate method on the *visitor* instance for each node encountered.

`compiler.compile(source, filename, mode, flags=None, dont_inherit=None)`

Compile the string *source*, a Python module, statement or expression, into a code object that can be executed by the `exec` statement or `eval()`. This function is a replacement for the built-in `compile()` function.

The *filename* will be used for run-time error messages.

The *mode* must be 'exec' to compile a module, 'single' to compile a single (interactive) statement, or 'eval' to compile an expression.

The *flags* and *dont\_inherit* arguments affect future-related statements, but are not supported yet.

`compiler.compileFile(source)`

Compiles the file *source* and generates a .pyc file.

The `compiler` package contains the following modules: `ast`, `consts`, `future`, `misc`, `pyassem`, `pycodegen`, `symbols`, `transformer`, and `visitor`.

## 32.2 Limitations

There are some problems with the error checking of the compiler package. The interpreter detects syntax errors in two distinct phases. One set of errors is detected by the interpreter's parser, the other set by the compiler. The compiler package relies on the interpreter's parser, so it get the first phases of error checking for free. It implements the second phase itself, and that implementation is incomplete. For example, the compiler package does not raise an error if a name appears more than once in an argument list: `def f(x, x): ...`

A future version of the compiler should fix these problems.

## 32.3 Python Abstract Syntax

The `compiler.ast` module defines an abstract syntax for Python. In the abstract syntax tree, each node represents a syntactic construct. The root of the tree is `Module` object.

The abstract syntax offers a higher level interface to parsed Python source code. The `parser` module and the compiler written in C for the Python interpreter use a concrete syntax tree. The concrete syntax is tied closely to the grammar description used for the Python parser. Instead of a single node for a construct, there are often several levels of nested nodes that are introduced by Python's precedence rules.

The abstract syntax tree is created by the `compiler.transformer` module. The transformer relies on the built-in Python parser to generate a concrete syntax tree. It generates an abstract syntax tree from the concrete tree.

The `transformer` module was created by Greg Stein and Bill Tutt for an experimental Python-to-C compiler. The current version contains a number of modifications and improvements, but the basic form of the abstract syntax and of the transformer are due to Stein and Tutt.

### 32.3.1 AST Nodes

The `compiler.ast` module is generated from a text file that describes each node type and its elements. Each node type is represented as a class that inherits from the abstract base class `compiler.ast.Node` and defines a set of named attributes for child nodes.

**class** `compiler.ast.Node`

The `Node` instances are created automatically by the parser generator. The recommended interface for specific `Node` instances is to use the public attributes to access child nodes. A public attribute may be bound to a single node or to a sequence of nodes, depending on the `Node` type. For example, the `bases` attribute of the `Class` node, is bound to a list of base class nodes, and the `doc` attribute is bound to a single node.

Each `Node` instance has a `lineno` attribute which may be `None`. XXX Not sure what the rules are for which nodes will have a useful `lineno`.

All `Node` objects offer the following methods:

**getChildren()**

Returns a flattened list of the child nodes and objects in the order they occur. Specifically, the order of the nodes is the order in which they appear in the Python grammar. Not all of the children are `Node` instances. The names of functions and classes, for example, are plain strings.

**getChildNodes()**

Returns a flattened list of the child nodes in the order they occur. This method is like `getChildren()`, except that it only returns those children that are `Node` instances.

Two examples illustrate the general structure of `Node` classes. The `while` statement is defined by the following grammar production:

```
while_stmt:    "while" expression ":" suite
              ["else" ":" suite]
```

The `While` node has three attributes: `test`, `body`, and `else_`. (If the natural name for an attribute is also a Python reserved word, it can't be used as an attribute name. An underscore is appended to the word to make it a legal identifier, hence `else_` instead of `else`.)

The `if` statement is more complicated because it can include several tests.

```
if_stmt: 'if' test ':' suite ('elif' test ':' suite)* ['else' ':' suite]
```

The `If` node only defines two attributes: `tests` and `else_`. The `tests` attribute is a sequence of test expression, consequent body pairs. There is one pair for each `if/elif` clause. The first element of the pair is the test expression. The second elements is a `Stmt` node that contains the code to execute if the test is true.

The `getChildren()` method of `If` returns a flat list of child nodes. If there are three `if/elif` clauses and no `else` clause, then `getChildren()` will return a list of six elements: the first test expression, the first `Stmt`, the second test expression, etc.

The following table lists each of the `Node` subclasses defined in `compiler.ast` and each of the public attributes available on their instances. The values of most of the attributes are themselves `Node` instances or sequences of instances. When the value is something other than an instance, the type is noted in the comment. The attributes are listed in the order in which they are returned by `getChildren()` and `getChildNodes()`.

Node type	Attribute	Value
Add	left	left operand
	right	right operand
And	nodes	list of operands
AssAttr		<i>attribute as target of assignment</i>
	expr	expression on the left-hand side of the dot
	attrname	the attribute name, a string
	flags	XXX
AssList	nodes	list of list elements being assigned to
AssName	name	name being assigned to
	flags	XXX
AssTuple	nodes	list of tuple elements being assigned to
Assert	test	the expression to be tested
	fail	the value of the <code>AssertionError</code>
Assign	nodes	a list of assignment targets, one per equal sign
	expr	the value being assigned
AugAssign	node	
	op	
	expr	
Backquote	expr	
Bitand	nodes	
Bitor	nodes	
Bitxor	nodes	
Break		
CallFunc	node	expression for the callee
	args	a list of arguments

Continued on next page

**Table 32.1 – continued from previous page**

	star_args	the extended *-arg value
	dstar_args	the extended **-arg value
Class	name	the name of the class, a string
	bases	a list of base classes
	doc	doc string, a string or None
	code	the body of the class statement
Compare	expr	
	ops	
Const	value	
Continue		
Decorators	nodes	List of function decorator expressions
Dict	items	
Discard	expr	
Div	left	
	right	
Ellipsis		
Expression	node	
Exec	expr	
	locals	
	globals	
FloorDiv	left	
	right	
For	assign	
	list	
	body	
	else_	
From	modname	
	names	
Function	decorators	Decorators or None
	name	name used in def, a string
	argnames	list of argument names, as strings
	defaults	list of default values
	flags	xxx
	doc	doc string, a string or None
	code	the body of the function
GenExpr	code	
GenExprFor	assign	
	iter	
	ifs	
GenExprIf	test	
GenExprInner	expr	
	quals	
Getattr	expr	
	attrname	
Global	names	
If	tests	
	else_	
Import	names	
Invert	expr	
Keyword	name	
	expr	
Lambda	argnames	

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**Table 32.1 – continued from previous page**

	defaults	
	flags	
	code	
LeftShift	left	
	right	
List	nodes	
ListComp	expr	
	quals	
ListCompFor	assign	
	list	
	ifs	
ListCompIf	test	
Mod	left	
	right	
Module	doc	doc string, a string or None
	node	body of the module, a Stmt
Mul	left	
	right	
Name	name	
Not	expr	
Or	nodes	
Pass		
Power	left	
	right	
Print	nodes	
	dest	
Printnl	nodes	
	dest	
Raise	expr1	
	expr2	
	expr3	
Return	value	
RightShift	left	
	right	
Slice	expr	
	flags	
	lower	
	upper	
Sliceobj	nodes	list of statements
Stmt	nodes	
Sub	left	
	right	
Subscript	expr	
	flags	
	subs	
TryExcept	body	
	handlers	
	else_	
TryFinally	body	
	final	
Tuple	nodes	
UnaryAdd	expr	

Continued on next page

Table 32.1 – continued from previous page

UnarySub	expr	
While	test body else_	
With	expr vars body	
Yield	value	

### 32.3.2 Assignment nodes

There is a collection of nodes used to represent assignments. Each assignment statement in the source code becomes a single `Assign` node in the AST. The `nodes` attribute is a list that contains a node for each assignment target. This is necessary because assignment can be chained, e.g. `a = b = 2`. Each `Node` in the list will be one of the following classes: `AssAttr`, `AssList`, `AssName`, or `AssTuple`.

Each target assignment node will describe the kind of object being assigned to: `AssName` for a simple name, e.g. `a = 1`. `AssAttr` for an attribute assigned, e.g. `a.x = 1`. `AssList` and `AssTuple` for list and tuple expansion respectively, e.g. `a, b, c = a_tuple`.

The target assignment nodes also have a `flags` attribute that indicates whether the node is being used for assignment or in a delete statement. The `AssName` is also used to represent a delete statement, e.g. `del x`.

When an expression contains several attribute references, an assignment or delete statement will contain only one `AssAttr` node – for the final attribute reference. The other attribute references will be represented as `Getattr` nodes in the `expr` attribute of the `AssAttr` instance.

### 32.3.3 Examples

This section shows several simple examples of ASTs for Python source code. The examples demonstrate how to use the `parse()` function, what the repr of an AST looks like, and how to access attributes of an AST node.

The first module defines a single function. Assume it is stored in `/tmp/doublelib.py`.

```
"""This is an example module.

This is the docstring.
"""

def double(x):
    "Return twice the argument"
    return x * 2
```

In the interactive interpreter session below, I have reformatted the long AST reprs for readability. The AST reprs use unqualified class names. If you want to create an instance from a repr, you must import the class names from the `compiler.ast` module.

```
>>> import compiler
>>> mod = compiler.parseFile("/tmp/doublelib.py")
>>> mod
Module('This is an example module.\n\nThis is the docstring.\n',
      Stmt([Function(None, 'double', ['x'], [], 0,
                    'Return twice the argument',
                    Stmt([Return(Mul((Name('x'), Const(2))))]))]))
```

```

>>> from compiler.ast import *
>>> Module('This is an example module.\n\nThis is the docstring.\n',
...       Stmt([Function(None, 'double', ['x'], [], 0,
...                       'Return twice the argument',
...                       Stmt([Return(Mul((Name('x'), Const(2))))]))]))
Module('This is an example module.\n\nThis is the docstring.\n',
       Stmt([Function(None, 'double', ['x'], [], 0,
                       'Return twice the argument',
                       Stmt([Return(Mul((Name('x'), Const(2))))]))]))
>>> mod.doc
'This is an example module.\n\nThis is the docstring.\n'
>>> for node in mod.node.nodes:
...     print node
...
Function(None, 'double', ['x'], [], 0, 'Return twice the argument',
         Stmt([Return(Mul((Name('x'), Const(2))))]))
>>> func = mod.node.nodes[0]
>>> func.code
Stmt([Return(Mul((Name('x'), Const(2))))])

```

## 32.4 Using Visitors to Walk ASTs

The visitor pattern is ... The `compiler` package uses a variant on the visitor pattern that takes advantage of Python's introspection features to eliminate the need for much of the visitor's infrastructure.

The classes being visited do not need to be programmed to accept visitors. The visitor need only define visit methods for classes it is specifically interested in; a default visit method can handle the rest.

XXX The magic `visit()` method for visitors.

```
compiler.visitor.walk(tree, visitor[, verbose])
```

**class** `compiler.visitor.ASTVisitor`

The `ASTVisitor` is responsible for walking over the tree in the correct order. A walk begins with a call to `preorder()`. For each node, it checks the `visitor` argument to `preorder()` for a method named 'visitNodeType,' where `NodeType` is the name of the node's class, e.g. for a `While` node a `visitWhile()` would be called. If the method exists, it is called with the node as its first argument.

The visitor method for a particular node type can control how child nodes are visited during the walk. The `ASTVisitor` modifies the visitor argument by adding a visit method to the visitor; this method can be used to visit a particular child node. If no visitor is found for a particular node type, the `default()` method is called.

`ASTVisitor` objects have the following methods:

XXX describe extra arguments

```
default(node[, ...])
```

```
dispatch(node[, ...])
```

```
preorder(tree, visitor)
```

## 32.5 Bytecode Generation

The code generator is a visitor that emits bytecodes. Each visit method can call the `emit()` method to emit a new bytecode. The basic code generator is specialized for modules, classes, and functions. An assembler converts that

emitted instructions to the low-level bytecode format. It handles things like generation of constant lists of code objects and calculation of jump offsets.

# MISCELLANEOUS SERVICES

The modules described in this chapter provide miscellaneous services that are available in all Python versions. Here's an overview:

## 33.1 `formatter` — Generic output formatting

This module supports two interface definitions, each with multiple implementations. The *formatter* interface is used by the `HTMLParser` class of the `htmllib` module, and the *writer* interface is required by the `formatter` interface.

Formatter objects transform an abstract flow of formatting events into specific output events on writer objects. Formatters manage several stack structures to allow various properties of a writer object to be changed and restored; writers need not be able to handle relative changes nor any sort of “change back” operation. Specific writer properties which may be controlled via formatter objects are horizontal alignment, font, and left margin indentations. A mechanism is provided which supports providing arbitrary, non-exclusive style settings to a writer as well. Additional interfaces facilitate formatting events which are not reversible, such as paragraph separation.

Writer objects encapsulate device interfaces. Abstract devices, such as file formats, are supported as well as physical devices. The provided implementations all work with abstract devices. The interface makes available mechanisms for setting the properties which formatter objects manage and inserting data into the output.

### 33.1.1 The Formatter Interface

Interfaces to create formatters are dependent on the specific formatter class being instantiated. The interfaces described below are the required interfaces which all formatters must support once initialized.

One data element is defined at the module level:

`formatter.AS_IS`

Value which can be used in the font specification passed to the `push_font()` method described below, or as the new value to any other `push_property()` method. Pushing the `AS_IS` value allows the corresponding `pop_property()` method to be called without having to track whether the property was changed.

The following attributes are defined for `formatter` instance objects:

`formatter.writer`

The writer instance with which the formatter interacts.

`formatter.end_paragraph(blanklines)`

Close any open paragraphs and insert at least *blanklines* before the next paragraph.

`formatter.add_line_break()`

Add a hard line break if one does not already exist. This does not break the logical paragraph.

`formatter.add_hor_rule(*args, **kw)`

Insert a horizontal rule in the output. A hard break is inserted if there is data in the current paragraph, but the logical paragraph is not broken. The arguments and keywords are passed on to the writer's `send_line_break()` method.

`formatter.add_flowling_data(data)`

Provide data which should be formatted with collapsed whitespace. Whitespace from preceding and successive calls to `add_flowling_data()` is considered as well when the whitespace collapse is performed. The data which is passed to this method is expected to be word-wrapped by the output device. Note that any word-wrapping still must be performed by the writer object due to the need to rely on device and font information.

`formatter.add_literal_data(data)`

Provide data which should be passed to the writer unchanged. Whitespace, including newline and tab characters, are considered legal in the value of `data`.

`formatter.add_label_data(format, counter)`

Insert a label which should be placed to the left of the current left margin. This should be used for constructing bulleted or numbered lists. If the `format` value is a string, it is interpreted as a format specification for `counter`, which should be an integer. The result of this formatting becomes the value of the label; if `format` is not a string it is used as the label value directly. The label value is passed as the only argument to the writer's `send_label_data()` method. Interpretation of non-string label values is dependent on the associated writer.

Format specifications are strings which, in combination with a counter value, are used to compute label values. Each character in the format string is copied to the label value, with some characters recognized to indicate a transform on the counter value. Specifically, the character '1' represents the counter value formatter as an Arabic number, the characters 'A' and 'a' represent alphabetic representations of the counter value in upper and lower case, respectively, and 'I' and 'i' represent the counter value in Roman numerals, in upper and lower case. Note that the alphabetic and roman transforms require that the counter value be greater than zero.

`formatter.flush_softspace()`

Send any pending whitespace buffered from a previous call to `add_flowling_data()` to the associated writer object. This should be called before any direct manipulation of the writer object.

`formatter.push_alignment(align)`

Push a new alignment setting onto the alignment stack. This may be `AS_IS` if no change is desired. If the alignment value is changed from the previous setting, the writer's `new_alignment()` method is called with the `align` value.

`formatter.pop_alignment()`

Restore the previous alignment.

`formatter.push_font((size, italic, bold, teletype))`

Change some or all font properties of the writer object. Properties which are not set to `AS_IS` are set to the values passed in while others are maintained at their current settings. The writer's `new_font()` method is called with the fully resolved font specification.

`formatter.pop_font()`

Restore the previous font.

`formatter.push_margin(margin)`

Increase the number of left margin indentations by one, associating the logical tag `margin` with the new indentation. The initial margin level is 0. Changed values of the logical tag must be true values; false values other than `AS_IS` are not sufficient to change the margin.

`formatter.pop_margin()`

Restore the previous margin.

`formatter.push_style(*styles)`

Push any number of arbitrary style specifications. All styles are pushed onto the styles stack in order. A tuple representing the entire stack, including `AS_IS` values, is passed to the writer's `new_styles()` method.

`formatter.pop_style([n=1])`  
 Pop the last *n* style specifications passed to `push_style()`. A tuple representing the revised stack, including `AS_IS` values, is passed to the writer's `new_styles()` method.

`formatter.set_spacing(spacing)`  
 Set the spacing style for the writer.

`formatter.assert_line_data([flag=1])`  
 Inform the formatter that data has been added to the current paragraph out-of-band. This should be used when the writer has been manipulated directly. The optional *flag* argument can be set to false if the writer manipulations produced a hard line break at the end of the output.

### 33.1.2 Formatter Implementations

Two implementations of formatter objects are provided by this module. Most applications may use one of these classes without modification or subclassing.

**class** `formatter.NullFormatter` (*writer*)  
 A formatter which does nothing. If *writer* is omitted, a `NullWriter` instance is created. No methods of the writer are called by `NullFormatter` instances. Implementations should inherit from this class if implementing a writer interface but don't need to inherit any implementation.

**class** `formatter.AbstractFormatter` (*writer*)  
 The standard formatter. This implementation has demonstrated wide applicability to many writers, and may be used directly in most circumstances. It has been used to implement a full-featured World Wide Web browser.

### 33.1.3 The Writer Interface

Interfaces to create writers are dependent on the specific writer class being instantiated. The interfaces described below are the required interfaces which all writers must support once initialized. Note that while most applications can use the `AbstractFormatter` class as a formatter, the writer must typically be provided by the application.

`writer.flush()`  
 Flush any buffered output or device control events.

`writer.new_alignment(align)`  
 Set the alignment style. The *align* value can be any object, but by convention is a string or `None`, where `None` indicates that the writer's "preferred" alignment should be used. Conventional *align* values are 'left', 'center', 'right', and 'justify'.

`writer.new_font(font)`  
 Set the font style. The value of *font* will be `None`, indicating that the device's default font should be used, or a tuple of the form (*size*, *italic*, *bold*, *teletype*). *Size* will be a string indicating the size of font that should be used; specific strings and their interpretation must be defined by the application. The *italic*, *bold*, and *teletype* values are Boolean values specifying which of those font attributes should be used.

`writer.new_margin(margin, level)`  
 Set the margin level to the integer *level* and the logical tag to *margin*. Interpretation of the logical tag is at the writer's discretion; the only restriction on the value of the logical tag is that it not be a false value for non-zero values of *level*.

`writer.new_spacing(spacing)`  
 Set the spacing style to *spacing*.

`writer.new_styles(styles)`  
 Set additional styles. The *styles* value is a tuple of arbitrary values; the value `AS_IS` should be ignored. The

*styles* tuple may be interpreted either as a set or as a stack depending on the requirements of the application and writer implementation.

`writer.send_line_break()`

Break the current line.

`writer.send_paragraph(blankline)`

Produce a paragraph separation of at least *blankline* blank lines, or the equivalent. The *blankline* value will be an integer. Note that the implementation will receive a call to `send_line_break()` before this call if a line break is needed; this method should not include ending the last line of the paragraph. It is only responsible for vertical spacing between paragraphs.

`writer.send_hor_rule(*args, **kw)`

Display a horizontal rule on the output device. The arguments to this method are entirely application- and writer-specific, and should be interpreted with care. The method implementation may assume that a line break has already been issued via `send_line_break()`.

`writer.send_flow_data(data)`

Output character data which may be word-wrapped and re-flowed as needed. Within any sequence of calls to this method, the writer may assume that spans of multiple whitespace characters have been collapsed to single space characters.

`writer.send_literal_data(data)`

Output character data which has already been formatted for display. Generally, this should be interpreted to mean that line breaks indicated by newline characters should be preserved and no new line breaks should be introduced. The data may contain embedded newline and tab characters, unlike data provided to the `send_formatted_data()` interface.

`writer.send_label_data(data)`

Set *data* to the left of the current left margin, if possible. The value of *data* is not restricted; treatment of non-string values is entirely application- and writer-dependent. This method will only be called at the beginning of a line.

### 33.1.4 Writer Implementations

Three implementations of the writer object interface are provided as examples by this module. Most applications will need to derive new writer classes from the `NullWriter` class.

**class** `formatter.NullWriter`

A writer which only provides the interface definition; no actions are taken on any methods. This should be the base class for all writers which do not need to inherit any implementation methods.

**class** `formatter.AbstractWriter`

A writer which can be used in debugging formatters, but not much else. Each method simply announces itself by printing its name and arguments on standard output.

**class** `formatter.DumbWriter` (*file=None, maxcol=72*)

Simple writer class which writes output on the file object passed in as *file* or, if *file* is `None`, on standard output. The output is simply word-wrapped to the number of columns specified by *maxcol*. This class is suitable for reflowing a sequence of paragraphs.

# MS WINDOWS SPECIFIC SERVICES

This chapter describes modules that are only available on MS Windows platforms.

## 34.1 `msilib` — Read and write Microsoft Installer files

*Platforms:* Windows

New in version 2.5. The `msilib` supports the creation of Microsoft Installer (`.msi`) files. Because these files often contain an embedded “cabinet” file (`.cab`), it also exposes an API to create CAB files. Support for reading `.cab` files is currently not implemented; read support for the `.msi` database is possible.

This package aims to provide complete access to all tables in an `.msi` file, therefore, it is a fairly low-level API. Two primary applications of this package are the `distutils` command `bdist_msi`, and the creation of Python installer package itself (although that currently uses a different version of `msilib`).

The package contents can be roughly split into four parts: low-level CAB routines, low-level MSI routines, higher-level MSI routines, and standard table structures.

`msilib.FCICreate` (*cabname*, *files*)

Create a new CAB file named *cabname*. *files* must be a list of tuples, each containing the name of the file on disk, and the name of the file inside the CAB file.

The files are added to the CAB file in the order they appear in the list. All files are added into a single CAB file, using the MSZIP compression algorithm.

Callbacks to Python for the various steps of MSI creation are currently not exposed.

`msilib.UuidCreate` ()

Return the string representation of a new unique identifier. This wraps the Windows API functions `UuidCreate` () and `UuidToString` ().

`msilib.OpenDatabase` (*path*, *persist*)

Return a new database object by calling `MsiOpenDatabase`. *path* is the file name of the MSI file; *persist* can be one of the constants `MSIDBOPEN_CREATEDIRECT`, `MSIDBOPEN_CREATE`, `MSIDBOPEN_DIRECT`, `MSIDBOPEN_READONLY`, or `MSIDBOPEN_TRANSACT`, and may include the flag `MSIDBOPEN_PATCHFILE`. See the Microsoft documentation for the meaning of these flags; depending on the flags, an existing database is opened, or a new one created.

`msilib.CreateRecord` (*count*)

Return a new record object by calling `MSICreateRecord` (). *count* is the number of fields of the record.

`msilib.init_database` (*name*, *schema*, *ProductName*, *ProductCode*, *ProductVersion*, *Manufacturer*)

Create and return a new database *name*, initialize it with *schema*, and set the properties *ProductName*, *ProductCode*, *ProductVersion*, and *Manufacturer*.

*schema* must be a module object containing `tables` and `_Validation_records` attributes; typically, `msilib.schema` should be used.

The database will contain just the schema and the validation records when this function returns.

`msilib.add_data(database, table, records)`  
Add all *records* to the table named *table* in *database*.

The *table* argument must be one of the predefined tables in the MSI schema, e.g. 'Feature', 'File', 'Component', 'Dialog', 'Control', etc.

*records* should be a list of tuples, each one containing all fields of a record according to the schema of the table. For optional fields, `None` can be passed.

Field values can be int or long numbers, strings, or instances of the Binary class.

**class** `msilib.Binary(filename)`  
Represents entries in the Binary table; inserting such an object using `add_data()` reads the file named *filename* into the table.

`msilib.add_tables(database, module)`  
Add all table content from *module* to *database*. *module* must contain an attribute *tables* listing all tables for which content should be added, and one attribute per table that has the actual content.

This is typically used to install the sequence tables.

`msilib.add_stream(database, name, path)`  
Add the file *path* into the `_Stream` table of *database*, with the stream name *name*.

`msilib.gen_uuid()`  
Return a new UUID, in the format that MSI typically requires (i.e. in curly braces, and with all hexdigits in upper-case).

### See Also:

[FCICreateFile](#) [UuidCreate](#) [UuidToString](#)

## 34.1.1 Database Objects

`Database.OpenView(sql)`  
Return a view object, by calling `MSIDatabaseOpenView()`. *sql* is the SQL statement to execute.

`Database.Commit()`  
Commit the changes pending in the current transaction, by calling `MSIDatabaseCommit()`.

`Database.GetSummaryInformation(count)`  
Return a new summary information object, by calling `MsiGetSummaryInformation()`. *count* is the maximum number of updated values.

### See Also:

[MSIDatabaseOpenView](#) [MSIDatabaseCommit](#) [MsiGetSummaryInformation](#)

## 34.1.2 View Objects

`View.Execute(params)`  
Execute the SQL query of the view, through `MSIViewExecute()`. If *params* is not `None`, it is a record describing actual values of the parameter tokens in the query.

`View.GetColumnInfo` (*kind*)

Return a record describing the columns of the view, through calling `MsiViewGetColumnInfo()`. *kind* can be either `MSICOLINFO_NAMES` or `MSICOLINFO_TYPES`.

`View.Fetch` ()

Return a result record of the query, through calling `MsiViewFetch()`.

`View.Modify` (*kind*, *data*)

Modify the view, by calling `MsiViewModify()`. *kind* can be one of `MSIMODIFY_SEEK`, `MSIMODIFY_REFRESH`, `MSIMODIFY_INSERT`, `MSIMODIFY_UPDATE`, `MSIMODIFY_ASSIGN`, `MSIMODIFY_REPLACE`, `MSIMODIFY_MERGE`, `MSIMODIFY_DELETE`, `MSIMODIFY_INSERT_TEMPORARY`, `MSIMODIFY_VALIDATE`, `MSIMODIFY_VALIDATE_NEW`, `MSIMODIFY_VALIDATE_FIELD`, or `MSIMODIFY_VALIDATE_DELETE`.

*data* must be a record describing the new data.

`View.Close` ()

Close the view, through `MsiViewClose()`.

#### See Also:

[MsiViewExecute](#) [MSIViewGetColumnInfo](#) [MsiViewFetch](#) [MsiViewModify](#) [MsiViewClose](#)

### 34.1.3 Summary Information Objects

`SummaryInformation.GetProperty` (*field*)

Return a property of the summary, through `MsiSummaryInfoGetProperty()`. *field* is the name of the property, and can be one of the constants `PID_CODEPAGE`, `PID_TITLE`, `PID_SUBJECT`, `PID_AUTHOR`, `PID_KEYWORDS`, `PID_COMMENTS`, `PID_TEMPLATE`, `PID_LASTAUTHOR`, `PID_REVNUMBER`, `PID_LASTPRINTED`, `PID_CREATE_DTM`, `PID_LASTSAVE_DTM`, `PID_PAGECOUNT`, `PID_WORDCOUNT`, `PID_CHARCOUNT`, `PID_APPNAME`, or `PID_SECURITY`.

`SummaryInformation.GetPropertyCount` ()

Return the number of summary properties, through `MsiSummaryInfoGetPropertyCount()`.

`SummaryInformation.SetProperty` (*field*, *value*)

Set a property through `MsiSummaryInfoSetProperty()`. *field* can have the same values as in `GetProperty()`, *value* is the new value of the property. Possible value types are integer and string.

`SummaryInformation.Persist` ()

Write the modified properties to the summary information stream, using `MsiSummaryInfoPersist()`.

#### See Also:

[MsiSummaryInfoGetProperty](#) [MsiSummaryInfoGetPropertyCount](#) [MsiSummaryInfoSetProperty](#) [MsiSummaryInfoPersist](#)

### 34.1.4 Record Objects

`Record.GetFieldCount` ()

Return the number of fields of the record, through `MsiRecordGetFieldCount()`.

`Record.GetInteger` (*field*)

Return the value of *field* as an integer where possible. *field* must be an integer.

`Record.GetString` (*field*)

Return the value of *field* as a string where possible. *field* must be an integer.

`Record.SetString (field, value)`

Set *field* to *value* through `MsiRecordSetString()`. *field* must be an integer; *value* a string.

`Record.SetStream (field, value)`

Set *field* to the contents of the file named *value*, through `MsiRecordSetStream()`. *field* must be an integer; *value* a string.

`Record.SetInteger (field, value)`

Set *field* to *value* through `MsiRecordSetInteger()`. Both *field* and *value* must be an integer.

`Record.ClearData ()`

Set all fields of the record to 0, through `MsiRecordClearData()`.

**See Also:**

`MsiRecordGetFieldCount` `MsiRecordSetString` `MsiRecordSetStream` `MsiRecordSetInteger` `MsiRecordClear`

### 34.1.5 Errors

All wrappers around MSI functions raise `MsiError`; the string inside the exception will contain more detail.

### 34.1.6 CAB Objects

**class** `msilib.CAB (name)`

The class `CAB` represents a CAB file. During MSI construction, files will be added simultaneously to the `Files` table, and to a CAB file. Then, when all files have been added, the CAB file can be written, then added to the MSI file.

*name* is the name of the CAB file in the MSI file.

**append** (*full, file, logical*)

Add the file with the pathname *full* to the CAB file, under the name *logical*. If there is already a file named *logical*, a new file name is created.

Return the index of the file in the CAB file, and the new name of the file inside the CAB file.

**commit** (*database*)

Generate a CAB file, add it as a stream to the MSI file, put it into the `Media` table, and remove the generated file from the disk.

### 34.1.7 Directory Objects

**class** `msilib.Directory (database, cab, basedir, physical, logical, default[, componentflags])`

Create a new directory in the `Directory` table. There is a current component at each point in time for the directory, which is either explicitly created through `start_component()`, or implicitly when files are added for the first time. Files are added into the current component, and into the cab file. To create a directory, a base directory object needs to be specified (can be `None`), the path to the physical directory, and a logical directory name. *default* specifies the `DefaultDir` slot in the directory table. *componentflags* specifies the default flags that new components get.

**start\_component** (`[component[, feature[, flags[, keyfile[, uuid]]]]])`

Add an entry to the `Component` table, and make this component the current component for this directory. If no component name is given, the directory name is used. If no *feature* is given, the current feature is used. If no *flags* are given, the directory's default flags are used. If no *keyfile* is given, the `KeyPath` is left null in the `Component` table.

**add\_file** (*file* [, *src* [, *version* [, *language* ] ] ])

Add a file to the current component of the directory, starting a new one if there is no current component. By default, the file name in the source and the file table will be identical. If the *src* file is specified, it is interpreted relative to the current directory. Optionally, a *version* and a *language* can be specified for the entry in the File table.

**glob** (*pattern* [, *exclude* ])

Add a list of files to the current component as specified in the glob pattern. Individual files can be excluded in the *exclude* list.

**remove\_pyc** ()

Remove .pyc/.pyo files on uninstall.

**See Also:**

[Directory Table](#) [File Table](#) [Component Table](#) [FeatureComponents Table](#)

### 34.1.8 Features

**class** `msilib.Feature` (*database*, *id*, *title*, *desc*, *display* [, *level=1* [, *parent* [, *directory* [, *attributes=0* ] ] ] ])

Add a new record to the `Feature` table, using the values *id*, *parent.id*, *title*, *desc*, *display*, *level*, *directory*, and *attributes*. The resulting feature object can be passed to the `start_component ()` method of `Directory`.

**set\_current** ()

Make this feature the current feature of `msilib`. New components are automatically added to the default feature, unless a feature is explicitly specified.

**See Also:**

[Feature Table](#)

### 34.1.9 GUI classes

`msilib` provides several classes that wrap the GUI tables in an MSI database. However, no standard user interface is provided; use `bdist_msi` to create MSI files with a user-interface for installing Python packages.

**class** `msilib.Control` (*dlg*, *name*)

Base class of the dialog controls. *dlg* is the dialog object the control belongs to, and *name* is the control's name.

**event** (*event*, *argument* [, *condition=1* [, *ordering* ] ])

Make an entry into the `ControlEvent` table for this control.

**mapping** (*event*, *attribute*)

Make an entry into the `EventMapping` table for this control.

**condition** (*action*, *condition*)

Make an entry into the `ControlCondition` table for this control.

**class** `msilib.RadioButtonGroup` (*dlg*, *name*, *property*)

Create a radio button control named *name*. *property* is the installer property that gets set when a radio button is selected.

**add** (*name*, *x*, *y*, *width*, *height*, *text* [, *value* ])

Add a radio button named *name* to the group, at the coordinates *x*, *y*, *width*, *height*, and with the label *text*. If *value* is omitted, it defaults to *name*.

**class** `msilib.Dialog` (*db, name, x, y, w, h, attr, title, first, default, cancel*)

Return a new `Dialog` object. An entry in the `Dialog` table is made, with the specified coordinates, dialog attributes, title, name of the first, default, and cancel controls.

**control** (*name, type, x, y, width, height, attributes, property, text, control\_next, help*)

Return a new `Control` object. An entry in the `Control` table is made with the specified parameters.

This is a generic method; for specific types, specialized methods are provided.

**text** (*name, x, y, width, height, attributes, text*)

Add and return a `Text` control.

**bitmap** (*name, x, y, width, height, text*)

Add and return a `Bitmap` control.

**line** (*name, x, y, width, height*)

Add and return a `Line` control.

**pushbutton** (*name, x, y, width, height, attributes, text, next\_control*)

Add and return a `PushButton` control.

**radiogroup** (*name, x, y, width, height, attributes, property, text, next\_control*)

Add and return a `RadioButtonGroup` control.

**checkbox** (*name, x, y, width, height, attributes, property, text, next\_control*)

Add and return a `CheckBox` control.

### See Also:

[Dialog Table Control Table Control Types ControlCondition Table ControlEvent Table EventMapping Table RadioButton Table](#)

## 34.1.10 Precomputed tables

`msilib` provides a few subpackages that contain only schema and table definitions. Currently, these definitions are based on MSI version 2.0.

### `msilib.schema`

This is the standard MSI schema for MSI 2.0, with the `tables` variable providing a list of table definitions, and `_Validation_records` providing the data for MSI validation.

### `msilib.sequence`

This module contains table contents for the standard sequence tables: `AdminExecuteSequence`, `AdminUISequence`, `AdvtExecuteSequence`, `InstallExecuteSequence`, and `InstallUISequence`.

### `msilib.text`

This module contains definitions for the `UIText` and `ActionText` tables, for the standard installer actions.

## 34.2 `msvcrt` – Useful routines from the MS VC++ runtime

*Platforms:* Windows

These functions provide access to some useful capabilities on Windows platforms. Some higher-level modules use these functions to build the Windows implementations of their services. For example, the `getpass` module uses this in the implementation of the `getpass()` function.

Further documentation on these functions can be found in the Platform API documentation.

The module implements both the normal and wide char variants of the console I/O api. The normal API deals only with ASCII characters and is of limited use for internationalized applications. The wide char API should be used where ever possible

### 34.2.1 File Operations

`msvcrt.locking` (*fd, mode, nbytes*)

Lock part of a file based on file descriptor *fd* from the C runtime. Raises `IOError` on failure. The locked region of the file extends from the current file position for *nbytes* bytes, and may continue beyond the end of the file. *mode* must be one of the `LK_*` constants listed below. Multiple regions in a file may be locked at the same time, but may not overlap. Adjacent regions are not merged; they must be unlocked individually.

`msvcrt.LK_LOCK`

`msvcrt.LK_RLCK`

Locks the specified bytes. If the bytes cannot be locked, the program immediately tries again after 1 second. If, after 10 attempts, the bytes cannot be locked, `IOError` is raised.

`msvcrt.LK_NBLCK`

`msvcrt.LK_NBRLCK`

Locks the specified bytes. If the bytes cannot be locked, `IOError` is raised.

`msvcrt.LK_UNLCK`

Unlocks the specified bytes, which must have been previously locked.

`msvcrt.setmode` (*fd, flags*)

Set the line-end translation mode for the file descriptor *fd*. To set it to text mode, *flags* should be `os.O_TEXT`; for binary, it should be `os.O_BINARY`.

`msvcrt.open_osfhandle` (*handle, flags*)

Create a C runtime file descriptor from the file handle *handle*. The *flags* parameter should be a bitwise OR of `os.O_APPEND`, `os.O_RDONLY`, and `os.O_TEXT`. The returned file descriptor may be used as a parameter to `os.fdopen()` to create a file object.

`msvcrt.get_osfhandle` (*fd*)

Return the file handle for the file descriptor *fd*. Raises `IOError` if *fd* is not recognized.

### 34.2.2 Console I/O

`msvcrt.kbhit` ()

Return true if a keypress is waiting to be read.

`msvcrt.getch` ()

Read a keypress and return the resulting character. Nothing is echoed to the console. This call will block if a keypress is not already available, but will not wait for `Enter` to be pressed. If the pressed key was a special function key, this will return `'\000'` or `'\xe0'`; the next call will return the keycode. The `Control-C` keypress cannot be read with this function.

`msvcrt.getwch` ()

Wide char variant of `getch()`, returning a Unicode value. New in version 2.6.

`msvcrt.getche` ()

Similar to `getch()`, but the keypress will be echoed if it represents a printable character.

`msvcrt.getwche` ()

Wide char variant of `getche()`, returning a Unicode value. New in version 2.6.

`msvcrt.putch` (*char*)

Print the character *char* to the console without buffering.

`msvcrt.putwch(unicode_char)`

Wide char variant of `putch()`, accepting a Unicode value. New in version 2.6.

`msvcrt.ungetch(char)`

Cause the character *char* to be “pushed back” into the console buffer; it will be the next character read by `getch()` or `getche()`.

`msvcrt.ungetwch(unicode_char)`

Wide char variant of `ungetch()`, accepting a Unicode value. New in version 2.6.

### 34.2.3 Other Functions

`msvcrt.heapmin()`

Force the `malloc()` heap to clean itself up and return unused blocks to the operating system. On failure, this raises `IOError`.

## 34.3 `_winreg` – Windows registry access

*Platforms:* Windows

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**Note:** The `_winreg` module has been renamed to `winreg` in Python 3. The *2to3* tool will automatically adapt imports when converting your sources to Python 3.

---

New in version 2.0. These functions expose the Windows registry API to Python. Instead of using an integer as the registry handle, a *handle object* is used to ensure that the handles are closed correctly, even if the programmer neglects to explicitly close them.

This module offers the following functions:

`_winreg.CloseKey(hkey)`

Closes a previously opened registry key. The *hkey* argument specifies a previously opened key.

---

**Note:** If *hkey* is not closed using this method (or via `hkey.Close()`), it is closed when the *hkey* object is destroyed by Python.

---

`_winreg.ConnectRegistry(computer_name, key)`

Establishes a connection to a predefined registry handle on another computer, and returns a *handle object*.

*computer\_name* is the name of the remote computer, of the form `r"\\computername"`. If `None`, the local computer is used.

*key* is the predefined handle to connect to.

The return value is the handle of the opened key. If the function fails, a `WindowsError` exception is raised.

`_winreg.CreateKey(key, sub_key)`

Creates or opens the specified key, returning a *handle object*.

*key* is an already open key, or one of the predefined `HKEY_* constants`.

*sub\_key* is a string that names the key this method opens or creates.

If *key* is one of the predefined keys, *sub\_key* may be `None`. In that case, the handle returned is the same key handle passed in to the function.

If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, a `WindowsError` exception is raised.

`_winreg.CreateKeyEx` (*key*, *sub\_key* [, *res* [, *sam* ] ])

Creates or opens the specified key, returning a *handle object*.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

*sub\_key* is a string that names the key this method opens or creates.

*res* is a reserved integer, and must be zero. The default is zero.

*sam* is an integer that specifies an access mask that describes the desired security access for the key. Default is `KEY_ALL_ACCESS`. See *Access Rights* for other allowed values.

If *key* is one of the predefined keys, *sub\_key* may be `None`. In that case, the handle returned is the same key handle passed in to the function.

If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, a `WindowsError` exception is raised.

New in version 2.7.

`_winreg.DeleteKey` (*key*, *sub\_key*)

Deletes the specified key.

*key* is an already open key, or any one of the predefined *HKEY\_\* constants*.

*sub\_key* is a string that must be a subkey of the key identified by the *key* parameter. This value must not be `None`, and the key may not have subkeys.

*This method can not delete keys with subkeys.*

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, a `WindowsError` exception is raised.

`_winreg.DeleteKeyEx` (*key*, *sub\_key* [, *sam* [, *res* ] ])

Deletes the specified key.

---

**Note:** The `DeleteKeyEx()` function is implemented with the `RegDeleteKeyEx` Windows API function, which is specific to 64-bit versions of Windows. See the `RegDeleteKeyEx` documentation.

---

*key* is an already open key, or any one of the predefined *HKEY\_\* constants*.

*sub\_key* is a string that must be a subkey of the key identified by the *key* parameter. This value must not be `None`, and the key may not have subkeys.

*res* is a reserved integer, and must be zero. The default is zero.

*sam* is an integer that specifies an access mask that describes the desired security access for the key. Default is `KEY_WOW64_64KEY`. See *Access Rights* for other allowed values.

*This method can not delete keys with subkeys.*

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, a `WindowsError` exception is raised.

On unsupported Windows versions, `NotImplementedError` is raised.

New in version 2.7.

`_winreg.DeleteValue` (*key*, *value*)

Removes a named value from a registry key.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

*value* is a string that identifies the value to remove.

`_winreg.EnumKey` (*key*, *index*)

Enumerates subkeys of an open registry key, returning a string.

*key* is an already open key, or any one of the predefined *HKEY\_\* constants*.

*index* is an integer that identifies the index of the key to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly until a `WindowsError` exception is raised, indicating, no more values are available.

`_winreg.EnumValue` (*key*, *index*)

Enumerates values of an open registry key, returning a tuple.

*key* is an already open key, or any one of the predefined *HKEY\_\* constants*.

*index* is an integer that identifies the index of the value to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly, until a `WindowsError` exception is raised, indicating no more values.

The result is a tuple of 3 items:

Index	Meaning
0	A string that identifies the value name
1	An object that holds the value data, and whose type depends on the underlying registry type
2	An integer that identifies the type of the value data (see table in docs for <code>SetValueEx()</code> )

`_winreg.ExpandEnvironmentStrings` (*unicode*)

Expands environment variable placeholders `%NAME%` in unicode strings like `REG_EXPAND_SZ`:

```
>>> ExpandEnvironmentStrings(u"%windir%")
u"C:\\Windows"
```

New in version 2.6.

`_winreg.FlushKey` (*key*)

Writes all the attributes of a key to the registry.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

It is not necessary to call `FlushKey()` to change a key. Registry changes are flushed to disk by the registry using its lazy flusher. Registry changes are also flushed to disk at system shutdown. Unlike `CloseKey()`, the `FlushKey()` method returns only when all the data has been written to the registry. An application should only call `FlushKey()` if it requires absolute certainty that registry changes are on disk.

---

**Note:** If you don't know whether a `FlushKey()` call is required, it probably isn't.

---

`_winreg.LoadKey` (*key*, *sub\_key*, *file\_name*)

Creates a subkey under the specified key and stores registration information from a specified file into that subkey.

*key* is a handle returned by `ConnectRegistry()` or one of the constants `HKEY_USERS` or `HKEY_LOCAL_MACHINE`.

*sub\_key* is a string that identifies the subkey to load.

*file\_name* is the name of the file to load registry data from. This file must have been created with the `SaveKey()` function. Under the file allocation table (FAT) file system, the filename may not have an extension.

A call to `LoadKey()` fails if the calling process does not have the `SE_RESTORE_PRIVILEGE` privilege. Note that privileges are different from permissions – see the [RegLoadKey documentation](#) for more details.

If `key` is a handle returned by `ConnectRegistry()`, then the path specified in `file_name` is relative to the remote computer.

`_winreg.OpenKey(key, sub_key[, res[, sam]])`

Opens the specified key, returning a *handle object*.

`key` is an already open key, or any one of the predefined `HKEY_* constants`.

`sub_key` is a string that identifies the sub\_key to open.

`res` is a reserved integer, and must be zero. The default is zero.

`sam` is an integer that specifies an access mask that describes the desired security access for the key. Default is `KEY_READ`. See [Access Rights](#) for other allowed values.

The result is a new handle to the specified key.

If the function fails, `WindowsError` is raised.

`_winreg.OpenKeyEx()`

The functionality of `OpenKeyEx()` is provided via `OpenKey()`, by the use of default arguments.

`_winreg.QueryInfoKey(key)`

Returns information about a key, as a tuple.

`key` is an already open key, or one of the predefined `HKEY_* constants`.

The result is a tuple of 3 items:

Index	Meaning
0	An integer giving the number of sub keys this key has.
1	An integer giving the number of values this key has.
2	A long integer giving when the key was last modified (if available) as 100's of nanoseconds since Jan 1, 1600.

`_winreg.QueryValue(key, sub_key)`

Retrieves the unnamed value for a key, as a string.

`key` is an already open key, or one of the predefined `HKEY_* constants`.

`sub_key` is a string that holds the name of the subkey with which the value is associated. If this parameter is `None` or empty, the function retrieves the value set by the `SetValue()` method for the key identified by `key`.

Values in the registry have name, type, and data components. This method retrieves the data for a key's first value that has a `NULL` name. But the underlying API call doesn't return the type, so always use `QueryValueEx()` if possible.

`_winreg.QueryValueEx(key, value_name)`

Retrieves the type and data for a specified value name associated with an open registry key.

`key` is an already open key, or one of the predefined `HKEY_* constants`.

`value_name` is a string indicating the value to query.

The result is a tuple of 2 items:

Index	Meaning
0	The value of the registry item.
1	An integer giving the registry type for this value (see table in docs for <code>SetValueEx()</code> )

`_winreg.SaveKey(key, file_name)`

Saves the specified key, and all its subkeys to the specified file.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

*file\_name* is the name of the file to save registry data to. This file cannot already exist. If this filename includes an extension, it cannot be used on file allocation table (FAT) file systems by the `LoadKey()` method.

If *key* represents a key on a remote computer, the path described by *file\_name* is relative to the remote computer. The caller of this method must possess the `SeBackupPrivilege` security privilege. Note that privileges are different than permissions – see the [Conflicts Between User Rights and Permissions](#) documentation for more details.

This function passes `NULL` for *security\_attributes* to the API.

`_winreg.SetValue(key, sub_key, type, value)`

Associates a value with a specified key.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

*sub\_key* is a string that names the subkey with which the value is associated.

*type* is an integer that specifies the type of the data. Currently this must be `REG_SZ`, meaning only strings are supported. Use the `SetValueEx()` function for support for other data types.

*value* is a string that specifies the new value.

If the key specified by the *sub\_key* parameter does not exist, the `SetValue` function creates it.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

The key identified by the *key* parameter must have been opened with `KEY_SET_VALUE` access.

`_winreg.SetValueEx(key, value_name, reserved, type, value)`

Stores data in the value field of an open registry key.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

*value\_name* is a string that names the subkey with which the value is associated.

*type* is an integer that specifies the type of the data. See [Value Types](#) for the available types.

*reserved* can be anything – zero is always passed to the API.

*value* is a string that specifies the new value.

This method can also set additional value and type information for the specified key. The key identified by the *key* parameter must have been opened with `KEY_SET_VALUE` access.

To open the key, use the `CreateKey()` or `OpenKey()` methods.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

`_winreg.DisableReflectionKey(key)`

Disables registry reflection for 32-bit processes running on a 64-bit operating system.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

Will generally raise `NotImplemented` if executed on a 32-bit operating system.

If the key is not on the reflection list, the function succeeds but has no effect. Disabling reflection for a key does not affect reflection of any subkeys.

`_winreg.EnableReflectionKey(key)`

Restores registry reflection for the specified disabled key.

*key* is an already open key, or one of the predefined *HKEY\_\* constants*.

Will generally raise `NotImplemented` if executed on a 32-bit operating system.

Restoring reflection for a key does not affect reflection of any subkeys.

`_winreg.QueryReflectionKey` (*key*)

Determines the reflection state for the specified key.

*key* is an already open key, or one of the predefined `HKEY_* constants`.

Returns `True` if reflection is disabled.

Will generally raise `NotImplemented` if executed on a 32-bit operating system.

### 34.3.1 Constants

The following constants are defined for use in many `_winreg` functions.

#### HKEY\_\* Constants

`_winreg.HKEY_CLASSES_ROOT`

Registry entries subordinate to this key define types (or classes) of documents and the properties associated with those types. Shell and COM applications use the information stored under this key.

`_winreg.HKEY_CURRENT_USER`

Registry entries subordinate to this key define the preferences of the current user. These preferences include the settings of environment variables, data about program groups, colors, printers, network connections, and application preferences.

`_winreg.HKEY_LOCAL_MACHINE`

Registry entries subordinate to this key define the physical state of the computer, including data about the bus type, system memory, and installed hardware and software.

`_winreg.HKEY_USERS`

Registry entries subordinate to this key define the default user configuration for new users on the local computer and the user configuration for the current user.

`_winreg.HKEY_PERFORMANCE_DATA`

Registry entries subordinate to this key allow you to access performance data. The data is not actually stored in the registry; the registry functions cause the system to collect the data from its source.

`_winreg.HKEY_CURRENT_CONFIG`

Contains information about the current hardware profile of the local computer system.

`_winreg.HKEY_DYN_DATA`

This key is not used in versions of Windows after 98.

#### Access Rights

For more information, see [Registry Key Security and Access](#).

`_winreg.KEY_ALL_ACCESS`

Combines the `STANDARD_RIGHTS_REQUIRED`, `KEY_QUERY_VALUE`, `KEY_SET_VALUE`, `KEY_CREATE_SUB_KEY`, `KEY_ENUMERATE_SUB_KEYS`, `KEY_NOTIFY`, and `KEY_CREATE_LINK` access rights.

`_winreg.KEY_WRITE`

Combines the `STANDARD_RIGHTS_WRITE`, `KEY_SET_VALUE`, and `KEY_CREATE_SUB_KEY` access rights.

### `_winreg.KEY_READ`

Combines the `STANDARD_RIGHTS_READ`, `KEY_QUERY_VALUE`, `KEY_ENUMERATE_SUB_KEYS`, and `KEY_NOTIFY` values.

### `_winreg.KEY_EXECUTE`

Equivalent to `KEY_READ`.

### `_winreg.KEY_QUERY_VALUE`

Required to query the values of a registry key.

### `_winreg.KEY_SET_VALUE`

Required to create, delete, or set a registry value.

### `_winreg.KEY_CREATE_SUB_KEY`

Required to create a subkey of a registry key.

### `_winreg.KEY_ENUMERATE_SUB_KEYS`

Required to enumerate the subkeys of a registry key.

### `_winreg.KEY_NOTIFY`

Required to request change notifications for a registry key or for subkeys of a registry key.

### `_winreg.KEY_CREATE_LINK`

Reserved for system use.

## 64-bit Specific

For more information, see [Accessing an Alternate Registry View](#).

### `_winreg.KEY_WOW64_64KEY`

Indicates that an application on 64-bit Windows should operate on the 64-bit registry view.

### `_winreg.KEY_WOW64_32KEY`

Indicates that an application on 64-bit Windows should operate on the 32-bit registry view.

## Value Types

For more information, see [Registry Value Types](#).

### `_winreg.REG_BINARY`

Binary data in any form.

### `_winreg.REG_DWORD`

32-bit number.

### `_winreg.REG_DWORD_LITTLE_ENDIAN`

A 32-bit number in little-endian format.

### `_winreg.REG_DWORD_BIG_ENDIAN`

A 32-bit number in big-endian format.

### `_winreg.REG_EXPAND_SZ`

Null-terminated string containing references to environment variables (`%PATH%`).

### `_winreg.REG_LINK`

A Unicode symbolic link.

### `_winreg.REG_MULTI_SZ`

A sequence of null-terminated strings, terminated by two null characters. (Python handles this termination automatically.)

`_winreg.REG_NONE`  
No defined value type.

`_winreg.REG_RESOURCE_LIST`  
A device-driver resource list.

`_winreg.REG_FULL_RESOURCE_DESCRIPTOR`  
A hardware setting.

`_winreg.REG_RESOURCE_REQUIREMENTS_LIST`  
A hardware resource list.

`_winreg.REG_SZ`  
A null-terminated string.

### 34.3.2 Registry Handle Objects

This object wraps a Windows HKEY object, automatically closing it when the object is destroyed. To guarantee cleanup, you can call either the `Close()` method on the object, or the `CloseKey()` function.

All registry functions in this module return one of these objects.

All registry functions in this module which accept a handle object also accept an integer, however, use of the handle object is encouraged.

Handle objects provide semantics for `__nonzero__()` – thus:

```
if handle:
    print "Yes"
```

will print `Yes` if the handle is currently valid (has not been closed or detached).

The object also support comparison semantics, so handle objects will compare true if they both reference the same underlying Windows handle value.

Handle objects can be converted to an integer (e.g., using the built-in `int()` function), in which case the underlying Windows handle value is returned. You can also use the `Detach()` method to return the integer handle, and also disconnect the Windows handle from the handle object.

`PyHKEY.Close()`  
Closes the underlying Windows handle.

If the handle is already closed, no error is raised.

`PyHKEY.Detach()`  
Detaches the Windows handle from the handle object.

The result is an integer (or long on 64 bit Windows) that holds the value of the handle before it is detached. If the handle is already detached or closed, this will return zero.

After calling this function, the handle is effectively invalidated, but the handle is not closed. You would call this function when you need the underlying Win32 handle to exist beyond the lifetime of the handle object.

`PyHKEY.__enter__()`  
`PyHKEY.__exit__(*exc_info)`

The HKEY object implements `__enter__()` and `__exit__()` and thus supports the context protocol for the `with` statement:

```
with OpenKey(HKEY_LOCAL_MACHINE, "foo") as key:
    ... # work with key
```

will automatically close `key` when control leaves the `with` block. New in version 2.6.

## 34.4 winsound — Sound-playing interface for Windows

*Platforms:* Windows

New in version 1.5.2. The `winsound` module provides access to the basic sound-playing machinery provided by Windows platforms. It includes functions and several constants.

`winsound.Beep` (*frequency, duration*)

Beep the PC's speaker. The *frequency* parameter specifies frequency, in hertz, of the sound, and must be in the range 37 through 32,767. The *duration* parameter specifies the number of milliseconds the sound should last. If the system is not able to beep the speaker, `RuntimeError` is raised. New in version 1.6.

`winsound.PlaySound` (*sound, flags*)

Call the underlying `PlaySound()` function from the Platform API. The *sound* parameter may be a filename, audio data as a string, or `None`. Its interpretation depends on the value of *flags*, which can be a bitwise ORed combination of the constants described below. If the *sound* parameter is `None`, any currently playing waveform sound is stopped. If the system indicates an error, `RuntimeError` is raised.

`winsound.MessageBeep` (*[type=MB\_OK]*)

Call the underlying `MessageBeep()` function from the Platform API. This plays a sound as specified in the registry. The *type* argument specifies which sound to play; possible values are `-1`, `MB_ICONASTERISK`, `MB_ICONEXCLAMATION`, `MB_ICONHAND`, `MB_ICONQUESTION`, and `MB_OK`, all described below. The value `-1` produces a "simple beep"; this is the final fallback if a sound cannot be played otherwise. New in version 2.3.

`winsound.SND_FILENAME`

The *sound* parameter is the name of a WAV file. Do not use with `SND_ALIAS`.

`winsound.SND_ALIAS`

The *sound* parameter is a sound association name from the registry. If the registry contains no such name, play the system default sound unless `SND_NODEFAULT` is also specified. If no default sound is registered, raise `RuntimeError`. Do not use with `SND_FILENAME`.

All Win32 systems support at least the following; most systems support many more:

<code>PlaySound()</code> name	Corresponding Control Panel Sound name
'SystemAsterisk'	Asterisk
'SystemExclamation'	Exclamation
'SystemExit'	Exit Windows
'SystemHand'	Critical Stop
'SystemQuestion'	Question

For example:

```
import winsound
# Play Windows exit sound.
winsound.PlaySound("SystemExit", winsound.SND_ALIAS)

# Probably play Windows default sound, if any is registered (because
# "*" probably isn't the registered name of any sound).
winsound.PlaySound("*", winsound.SND_ALIAS)
```

`winsound.SND_LOOP`

Play the sound repeatedly. The `SND_ASYNC` flag must also be used to avoid blocking. Cannot be used with `SND_MEMORY`.

`winsound.SND_MEMORY`

The *sound* parameter to `PlaySound()` is a memory image of a WAV file, as a string.

---

**Note:** This module does not support playing from a memory image asynchronously, so a combination of this flag and `SND_ASYNC` will raise `RuntimeError`.

---

`winsound.SND_PURGE`  
Stop playing all instances of the specified sound.

---

**Note:** This flag is not supported on modern Windows platforms.

---

`winsound.SND_ASYNC`  
Return immediately, allowing sounds to play asynchronously.

`winsound.SND_NODEFAULT`  
If the specified sound cannot be found, do not play the system default sound.

`winsound.SND_NOSTOP`  
Do not interrupt sounds currently playing.

`winsound.SND_NOWAIT`  
Return immediately if the sound driver is busy.

`winsound.MB_ICONASTERISK`  
Play the `SystemDefault` sound.

`winsound.MB_ICONEXCLAMATION`  
Play the `SystemExclamation` sound.

`winsound.MB_ICONHAND`  
Play the `SystemHand` sound.

`winsound.MB_ICONQUESTION`  
Play the `SystemQuestion` sound.

`winsound.MB_OK`  
Play the `SystemDefault` sound.



# UNIX SPECIFIC SERVICES

The modules described in this chapter provide interfaces to features that are unique to the Unix operating system, or in some cases to some or many variants of it. Here's an overview:

## 35.1 `posix` — The most common POSIX system calls

*Platforms:* Unix

This module provides access to operating system functionality that is standardized by the C Standard and the POSIX standard (a thinly disguised Unix interface).

**Do not import this module directly.** Instead, import the module `os`, which provides a *portable* version of this interface. On Unix, the `os` module provides a superset of the `posix` interface. On non-Unix operating systems the `posix` module is not available, but a subset is always available through the `os` interface. Once `os` is imported, there is *no* performance penalty in using it instead of `posix`. In addition, `os` provides some additional functionality, such as automatically calling `putenv()` when an entry in `os.environ` is changed.

Errors are reported as exceptions; the usual exceptions are given for type errors, while errors reported by the system calls raise `OSError`.

### 35.1.1 Large File Support

Several operating systems (including AIX, HP-UX, Irix and Solaris) provide support for files that are larger than 2 GB from a C programming model where `int` and `long` are 32-bit values. This is typically accomplished by defining the relevant size and offset types as 64-bit values. Such files are sometimes referred to as *large files*.

Large file support is enabled in Python when the size of an `off_t` is larger than a `long` and the `long long` type is available and is at least as large as an `off_t`. Python longs are then used to represent file sizes, offsets and other values that can exceed the range of a Python `int`. It may be necessary to configure and compile Python with certain compiler flags to enable this mode. For example, it is enabled by default with recent versions of Irix, but with Solaris 2.6 and 2.7 you need to do something like:

```
CFLAGS="`getconf LFS_CFLAGS`" OPT="-g -O2 $CFLAGS" \  
./configure
```

On large-file-capable Linux systems, this might work:

```
CFLAGS='-D_LARGEFILE64_SOURCE -D_FILE_OFFSET_BITS=64' OPT="-g -O2 $CFLAGS" \  
./configure
```

## 35.1.2 Notable Module Contents

In addition to many functions described in the `os` module documentation, `posix` defines the following data item:

### `posix.environ`

A dictionary representing the string environment at the time the interpreter was started. For example, `environ['HOME']` is the pathname of your home directory, equivalent to `getenv("HOME")` in C.

Modifying this dictionary does not affect the string environment passed on by `execv()`, `popen()` or `system()`; if you need to change the environment, pass `environ` to `execve()` or add variable assignments and export statements to the command string for `system()` or `popen()`.

---

**Note:** The `os` module provides an alternate implementation of `environ` which updates the environment on modification. Note also that updating `os.environ` will render this dictionary obsolete. Use of the `os` module version of this is recommended over direct access to the `posix` module.

---

## 35.2 `pwd` — The password database

*Platforms:* Unix

This module provides access to the Unix user account and password database. It is available on all Unix versions.

Password database entries are reported as a tuple-like object, whose attributes correspond to the members of the `passwd` structure (Attribute field below, see `<pwd.h>`):

Index	Attribute	Meaning
0	<code>pw_name</code>	Login name
1	<code>pw_passwd</code>	Optional encrypted password
2	<code>pw_uid</code>	Numerical user ID
3	<code>pw_gid</code>	Numerical group ID
4	<code>pw_gecos</code>	User name or comment field
5	<code>pw_dir</code>	User home directory
6	<code>pw_shell</code>	User command interpreter

The `uid` and `gid` items are integers, all others are strings. `KeyError` is raised if the entry asked for cannot be found.

---

**Note:** In traditional Unix the field `pw_passwd` usually contains a password encrypted with a DES derived algorithm (see module `crypt`). However most modern unices use a so-called *shadow password* system. On those unices the `pw_passwd` field only contains an asterisk (`'*'`) or the letter `'x'` where the encrypted password is stored in a file `/etc/shadow` which is not world readable. Whether the `pw_passwd` field contains anything useful is system-dependent. If available, the `spwd` module should be used where access to the encrypted password is required.

---

It defines the following items:

`pwd.getpwuid(uid)`

Return the password database entry for the given numeric user ID.

`pwd.getpwnam(name)`

Return the password database entry for the given user name.

`pwd.getpwall()`

Return a list of all available password database entries, in arbitrary order.

**See Also:**

**Module `grp`** An interface to the group database, similar to this.

**Module `spwd`** An interface to the shadow password database, similar to this.

## 35.3 `spwd` — The shadow password database

*Platforms:* Unix

New in version 2.5. This module provides access to the Unix shadow password database. It is available on various Unix versions.

You must have enough privileges to access the shadow password database (this usually means you have to be root).

Shadow password database entries are reported as a tuple-like object, whose attributes correspond to the members of the `spwd` structure (Attribute field below, see `<shadow.h>`):

Index	Attribute	Meaning
0	<code>sp_nam</code>	Login name
1	<code>sp_pwd</code>	Encrypted password
2	<code>sp_lstchg</code>	Date of last change
3	<code>sp_min</code>	Minimal number of days between changes
4	<code>sp_max</code>	Maximum number of days between changes
5	<code>sp_warn</code>	Number of days before password expires to warn user about it
6	<code>sp_inact</code>	Number of days after password expires until account is blocked
7	<code>sp_expire</code>	Number of days since 1970-01-01 until account is disabled
8	<code>sp_flag</code>	Reserved

The `sp_nam` and `sp_pwd` items are strings, all others are integers. `KeyError` is raised if the entry asked for cannot be found.

It defines the following items:

`spwd.getspnam(name)`

Return the shadow password database entry for the given user name.

`spwd.getspall()`

Return a list of all available shadow password database entries, in arbitrary order.

**See Also:**

**Module `grp`** An interface to the group database, similar to this.

**Module `pwd`** An interface to the normal password database, similar to this.

## 35.4 `grp` — The group database

*Platforms:* Unix

This module provides access to the Unix group database. It is available on all Unix versions.

Group database entries are reported as a tuple-like object, whose attributes correspond to the members of the `group` structure (Attribute field below, see `<pwd.h>`):

Index	Attribute	Meaning
0	<code>gr_name</code>	the name of the group
1	<code>gr_passwd</code>	the (encrypted) group password; often empty
2	<code>gr_gid</code>	the numerical group ID
3	<code>gr_mem</code>	all the group member's user names

The `gid` is an integer, `name` and `password` are strings, and the `member list` is a list of strings. (Note that most users are not explicitly listed as members of the group they are in according to the password database. Check both databases to get complete membership information. Also note that a `gr_name` that starts with a `+` or `-` is likely to be a YP/NIS reference and may not be accessible via `getgrnam()` or `getgrgid()`.)

It defines the following items:

`grp.getgrgid(gid)`

Return the group database entry for the given numeric group ID. `KeyError` is raised if the entry asked for cannot be found.

`grp.getgrnam(name)`

Return the group database entry for the given group name. `KeyError` is raised if the entry asked for cannot be found.

`grp.getgrall()`

Return a list of all available group entries, in arbitrary order.

**See Also:**

**Module `pwd`** An interface to the user database, similar to this.

**Module `spwd`** An interface to the shadow password database, similar to this.

## 35.5 `crypt` — Function to check Unix passwords

*Platforms:* Unix

This module implements an interface to the `crypt(3)` routine, which is a one-way hash function based upon a modified DES algorithm; see the Unix man page for further details. Possible uses include allowing Python scripts to accept typed passwords from the user, or attempting to crack Unix passwords with a dictionary.

Notice that the behavior of this module depends on the actual implementation of the `crypt(3)` routine in the running system. Therefore, any extensions available on the current implementation will also be available on this module.

`crypt.crypt(word, salt)`

`word` will usually be a user's password as typed at a prompt or in a graphical interface. `salt` is usually a random two-character string which will be used to perturb the DES algorithm in one of 4096 ways. The characters in `salt` must be in the set `[./a-zA-Z0-9]`. Returns the hashed password as a string, which will be composed of characters from the same alphabet as the salt (the first two characters represent the salt itself).

Since a few `crypt(3)` extensions allow different values, with different sizes in the `salt`, it is recommended to use the full crypted password as salt when checking for a password.

A simple example illustrating typical use:

```
import crypt, getpass, pwd
```

```
def login():
    username = raw_input('Python login:')
    cryptpasswd = pwd.getpwnam(username)[1]
    if cryptpasswd:
        if cryptpasswd == 'x' or cryptpasswd == '*':
            raise NotImplementedError(
                "Sorry, currently no support for shadow passwords")
        cleartext = getpass.getpass()
        return crypt.crypt(cleartext, cryptpasswd) == cryptpasswd
    else:
        return 1
```

## 35.6 dl — Call C functions in shared objects

*Platforms:* Unix

Deprecated since version 2.6: The `dl` module has been removed in Python 3. Use the `ctypes` module instead. The `dl` module defines an interface to the `dlopen()` function, which is the most common interface on Unix platforms for handling dynamically linked libraries. It allows the program to call arbitrary functions in such a library.

**Warning:** The `dl` module bypasses the Python type system and error handling. If used incorrectly it may cause segmentation faults, crashes or other incorrect behaviour.

**Note:** This module will not work unless `sizeof(int) == sizeof(long) == sizeof(char *)`. If this is not the case, `SystemError` will be raised on import.

The `dl` module defines the following function:

`dl.open(name[, mode=RTLD_LAZY])`  
 Open a shared object file, and return a handle. Mode signifies late binding (`RTLD_LAZY`) or immediate binding (`RTLD_NOW`). Default is `RTLD_LAZY`. Note that some systems do not support `RTLD_NOW`.  
 Return value is a `dlobjct`.

The `dl` module defines the following constants:

`dl.RTLD_LAZY`  
 Useful as an argument to `open()`.  
`dl.RTLD_NOW`  
 Useful as an argument to `open()`. Note that on systems which do not support immediate binding, this constant will not appear in the module. For maximum portability, use `hasattr()` to determine if the system supports immediate binding.

The `dl` module defines the following exception:

**exception `dl.error`**  
 Exception raised when an error has occurred inside the dynamic loading and linking routines.

Example:

```
>>> import dl, time
>>> a=dl.open('/lib/libc.so.6')
>>> a.call('time'), time.time()
(929723914, 929723914.498)
```

This example was tried on a Debian GNU/Linux system, and is a good example of the fact that using this module is usually a bad alternative.

### 35.6.1 Dl Objects

Dl objects, as returned by `open()` above, have the following methods:

`dl.close()`  
 Free all resources, except the memory.  
`dl.sym(name)`  
 Return the pointer for the function named `name`, as a number, if it exists in the referenced shared object, otherwise `None`. This is useful in code like:

```
>>> if a.sym('time') :
...     a.call('time')
... else:
...     time.time()
```

(Note that this function will return a non-zero number, as zero is the *NULL* pointer)

`dl.call(name[, arg1[, arg2... ]])`

Call the function named *name* in the referenced shared object. The arguments must be either Python integers, which will be passed as is, Python strings, to which a pointer will be passed, or *None*, which will be passed as *NULL*. Note that strings should only be passed to functions as `const char*`, as Python will not like its string mutated.

There must be at most 10 arguments, and arguments not given will be treated as *None*. The function's return value must be a C `long`, which is a Python integer.

## 35.7 `termios` — POSIX style tty control

*Platforms:* Unix

This module provides an interface to the POSIX calls for tty I/O control. For a complete description of these calls, see the POSIX or Unix manual pages. It is only available for those Unix versions that support POSIX *termios* style tty I/O control (and then only if configured at installation time).

All functions in this module take a file descriptor *fd* as their first argument. This can be an integer file descriptor, such as returned by `sys.stdin.fileno()`, or a file object, such as `sys.stdin` itself.

This module also defines all the constants needed to work with the functions provided here; these have the same name as their counterparts in C. Please refer to your system documentation for more information on using these terminal control interfaces.

The module defines the following functions:

`termios.tcgetattr(fd)`

Return a list containing the tty attributes for file descriptor *fd*, as follows: `[iflag, oflag, cflag, lflag, ispeed, ospeed, cc]` where *cc* is a list of the tty special characters (each a string of length 1, except the items with indices `VMIN` and `VTIME`, which are integers when these fields are defined). The interpretation of the flags and the speeds as well as the indexing in the *cc* array must be done using the symbolic constants defined in the `termios` module.

`termios.tcsetattr(fd, when, attributes)`

Set the tty attributes for file descriptor *fd* from the *attributes*, which is a list like the one returned by `tcgetattr()`. The *when* argument determines when the attributes are changed: `TCSANOW` to change immediately, `TCSADRAIN` to change after transmitting all queued output, or `TCSAFLUSH` to change after transmitting all queued output and discarding all queued input.

`termios.tcsendbreak(fd, duration)`

Send a break on file descriptor *fd*. A zero *duration* sends a break for 0.25–0.5 seconds; a nonzero *duration* has a system dependent meaning.

`termios.tcdrain(fd)`

Wait until all output written to file descriptor *fd* has been transmitted.

`termios.tcflush(fd, queue)`

Discard queued data on file descriptor *fd*. The *queue* selector specifies which queue: `TCIFLUSH` for the input queue, `TCOFLUSH` for the output queue, or `TCIOFLUSH` for both queues.

`termios.tcflow` (*fd*, *action*)

Suspend or resume input or output on file descriptor *fd*. The *action* argument can be TCOOFF to suspend output, TCOON to restart output, TCIOFF to suspend input, or TCION to restart input.

**See Also:**

**Module** `tty` Convenience functions for common terminal control operations.

### 35.7.1 Example

Here's a function that prompts for a password with echoing turned off. Note the technique using a separate `tcgetattr()` call and a `try ... finally` statement to ensure that the old `tty` attributes are restored exactly no matter what happens:

```
def getpass(prompt="Password: "):
    import termios, sys
    fd = sys.stdin.fileno()
    old = termios.tcgetattr(fd)
    new = termios.tcgetattr(fd)
    new[3] = new[3] & ~termios.ECHO           # lflags
    try:
        termios.tcsetattr(fd, termios.TCSADRAIN, new)
        passwd = raw_input(prompt)
    finally:
        termios.tcsetattr(fd, termios.TCSADRAIN, old)
    return passwd
```

## 35.8 `tty` — Terminal control functions

*Platforms:* Unix

The `tty` module defines functions for putting the `tty` into cbreak and raw modes.

Because it requires the `termios` module, it will work only on Unix.

The `tty` module defines the following functions:

`tty.setraw` (*fd*[, *when* ])

Change the mode of the file descriptor *fd* to raw. If *when* is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to `termios.tcsetattr()`.

`tty.setcbreak` (*fd*[, *when* ])

Change the mode of file descriptor *fd* to cbreak. If *when* is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to `termios.tcsetattr()`.

**See Also:**

**Module** `termios` Low-level terminal control interface.

## 35.9 `pty` — Pseudo-terminal utilities

*Platforms:* Linux

The `pty` module defines operations for handling the pseudo-terminal concept: starting another process and being able to write to and read from its controlling terminal programmatically.

Because pseudo-terminal handling is highly platform dependent, there is code to do it only for Linux. (The Linux code is supposed to work on other platforms, but hasn't been tested yet.)

The `pty` module defines the following functions:

`pty.fork()`

Fork. Connect the child's controlling terminal to a pseudo-terminal. Return value is `(pid, fd)`. Note that the child gets `pid 0`, and the `fd` is *invalid*. The parent's return value is the `pid` of the child, and `fd` is a file descriptor connected to the child's controlling terminal (and also to the child's standard input and output).

`pty.openpty()`

Open a new pseudo-terminal pair, using `os.openpty()` if possible, or emulation code for generic Unix systems. Return a pair of file descriptors `(master, slave)`, for the master and the slave end, respectively.

`pty.spawn(argv[, master_read[, stdin_read]])`

Spawn a process, and connect its controlling terminal with the current process's standard io. This is often used to baffle programs which insist on reading from the controlling terminal.

The functions `master_read` and `stdin_read` should be functions which read from a file descriptor. The defaults try to read 1024 bytes each time they are called.

## 35.10 `fcntl` — The `fcntl()` and `ioctl()` system calls

*Platforms:* Unix

This module performs file control and I/O control on file descriptors. It is an interface to the `fcntl()` and `ioctl()` Unix routines.

All functions in this module take a file descriptor `fd` as their first argument. This can be an integer file descriptor, such as returned by `sys.stdin.fileno()`, or a file object, such as `sys.stdin` itself, which provides a `fileno()` which returns a genuine file descriptor.

The module defines the following functions:

`fcntl.fcntl(fd, op[, arg])`

Perform the requested operation on file descriptor `fd` (file objects providing a `fileno()` method are accepted as well). The operation is defined by `op` and is operating system dependent. These codes are also found in the `fcntl` module. The argument `arg` is optional, and defaults to the integer value 0. When present, it can either be an integer value, or a string. With the argument missing or an integer value, the return value of this function is the integer return value of the C `fcntl()` call. When the argument is a string it represents a binary structure, e.g. created by `struct.pack()`. The binary data is copied to a buffer whose address is passed to the C `fcntl()` call. The return value after a successful call is the contents of the buffer, converted to a string object. The length of the returned string will be the same as the length of the `arg` argument. This is limited to 1024 bytes. If the information returned in the buffer by the operating system is larger than 1024 bytes, this is most likely to result in a segmentation violation or a more subtle data corruption.

If the `fcntl()` fails, an `IOError` is raised.

`fcntl.ioctl(fd, op[, arg[, mutate_flag]])`

This function is identical to the `fcntl()` function, except that the operations are typically defined in the library module `termios` and the argument handling is even more complicated.

The `op` parameter is limited to values that can fit in 32-bits.

The parameter `arg` can be one of an integer, absent (treated identically to the integer 0), an object supporting the read-only buffer interface (most likely a plain Python string) or an object supporting the read-write buffer interface.

In all but the last case, behaviour is as for the `fcntl()` function.

If a mutable buffer is passed, then the behaviour is determined by the value of the *mutate\_flag* parameter.

If it is false, the buffer's mutability is ignored and behaviour is as for a read-only buffer, except that the 1024 byte limit mentioned above is avoided – so long as the buffer you pass is at least as long as what the operating system wants to put there, things should work.

If *mutate\_flag* is true, then the buffer is (in effect) passed to the underlying `ioctl()` system call, the latter's return code is passed back to the calling Python, and the buffer's new contents reflect the action of the `ioctl()`. This is a slight simplification, because if the supplied buffer is less than 1024 bytes long it is first copied into a static buffer 1024 bytes long which is then passed to `ioctl()` and copied back into the supplied buffer.

If *mutate\_flag* is not supplied, then from Python 2.5 it defaults to true, which is a change from versions 2.3 and 2.4. Supply the argument explicitly if version portability is a priority.

An example:

```
>>> import array, fcntl, struct, termios, os
>>> os.getpgrp()
13341
>>> struct.unpack('h', fcntl.ioctl(0, termios.TIOCGPGRP, " "))[0]
13341
>>> buf = array.array('h', [0])
>>> fcntl.ioctl(0, termios.TIOCGPGRP, buf, 1)
0
>>> buf
array('h', [13341])
```

`fcntl.flock(fd, op)`

Perform the lock operation *op* on file descriptor *fd* (file objects providing a `fileno()` method are accepted as well). See the Unix manual *flock(2)* for details. (On some systems, this function is emulated using `fcntl()`.)

`fcntl.lockf(fd, operation[, length[, start[, whence ] ] ])`

This is essentially a wrapper around the `fcntl()` locking calls. *fd* is the file descriptor of the file to lock or unlock, and *operation* is one of the following values:

- LOCK\_UN – unlock
- LOCK\_SH – acquire a shared lock
- LOCK\_EX – acquire an exclusive lock

When *operation* is LOCK\_SH or LOCK\_EX, it can also be bitwise ORed with LOCK\_NB to avoid blocking on lock acquisition. If LOCK\_NB is used and the lock cannot be acquired, an `IOError` will be raised and the exception will have an *errno* attribute set to EACCES or EAGAIN (depending on the operating system; for portability, check for both values). On at least some systems, LOCK\_EX can only be used if the file descriptor refers to a file opened for writing.

*length* is the number of bytes to lock, *start* is the byte offset at which the lock starts, relative to *whence*, and *whence* is as with `fileobj.seek()`, specifically:

- 0 – relative to the start of the file (SEEK\_SET)
- 1 – relative to the current buffer position (SEEK\_CUR)
- 2 – relative to the end of the file (SEEK\_END)

The default for *start* is 0, which means to start at the beginning of the file. The default for *length* is 0 which means to lock to the end of the file. The default for *whence* is also 0.

Examples (all on a SVR4 compliant system):

```
import struct, fcntl, os
```

```
f = open(...)
rv = fcntl.fcntl(f, fcntl.F_SETFL, os.O_NDELAY)

lockdata = struct.pack('hhllhh', fcntl.F_WRLCK, 0, 0, 0, 0, 0)
rv = fcntl.fcntl(f, fcntl.F_SETLKW, lockdata)
```

Note that in the first example the return value variable *rv* will hold an integer value; in the second example it will hold a string value. The structure lay-out for the *lockdata* variable is system dependent — therefore using the `flock()` call may be better.

**See Also:**

**Module `os`** If the locking flags `O_SHLOCK` and `O_EXLOCK` are present in the `os` module (on BSD only), the `os.open()` function provides an alternative to the `lockf()` and `flock()` functions.

## 35.11 pipes — Interface to shell pipelines

*Platforms:* Unix

**Source code:** `Lib/pipes.py`

---

The `pipes` module defines a class to abstract the concept of a *pipeline* — a sequence of converters from one file to another.

Because the module uses `/bin/sh` command lines, a POSIX or compatible shell for `os.system()` and `os.popen()` is required.

The `pipes` module defines the following class:

```
class pipes.Template
    An abstraction of a pipeline.
```

Example:

```
>>> import pipes
>>> t=pipes.Template()
>>> t.append('tr a-z A-Z', '--')
>>> f=t.open('/tmp/1', 'w')
>>> f.write('hello world')
>>> f.close()
>>> open('/tmp/1').read()
'HELLO WORLD'
```

### 35.11.1 Template Objects

Template objects following methods:

`Template.reset()`  
Restore a pipeline template to its initial state.

`Template.clone()`  
Return a new, equivalent, pipeline template.

Template.**debug** (*flag*)

If *flag* is true, turn debugging on. Otherwise, turn debugging off. When debugging is on, commands to be executed are printed, and the shell is given `set -x` command to be more verbose.

Template.**append** (*cmd, kind*)

Append a new action at the end. The *cmd* variable must be a valid bourne shell command. The *kind* variable consists of two letters.

The first letter can be either of `'-'` (which means the command reads its standard input), `'f'` (which means the commands reads a given file on the command line) or `'.'` (which means the commands reads no input, and hence must be first.)

Similarly, the second letter can be either of `'-'` (which means the command writes to standard output), `'f'` (which means the command writes a file on the command line) or `'.'` (which means the command does not write anything, and hence must be last.)

Template.**prepend** (*cmd, kind*)

Add a new action at the beginning. See `append()` for explanations of the arguments.

Template.**open** (*file, mode*)

Return a file-like object, open to *file*, but read from or written to by the pipeline. Note that only one of `'r'`, `'w'` may be given.

Template.**copy** (*infile, outfile*)

Copy *infile* to *outfile* through the pipe.

## 35.12 `posixfile` — File-like objects with locking support

*Platforms:* Unix

Deprecated since version 1.5: The locking operation that this module provides is done better and more portably by the `fcntl.lockf()` call. This module implements some additional functionality over the built-in file objects. In particular, it implements file locking, control over the file flags, and an easy interface to duplicate the file object. The module defines a new file object, the `posixfile` object. It has all the standard file object methods and adds the methods described below. This module only works for certain flavors of Unix, since it uses `fcntl.fcntl()` for file locking.

To instantiate a `posixfile` object, use the `posixfile.open()` function. The resulting object looks and feels roughly the same as a standard file object.

The `posixfile` module defines the following constants:

`posixfile.SEEK_SET`

Offset is calculated from the start of the file.

`posixfile.SEEK_CUR`

Offset is calculated from the current position in the file.

`posixfile.SEEK_END`

Offset is calculated from the end of the file.

The `posixfile` module defines the following functions:

`posixfile.open` (*filename* [, *mode* [, *bufsize* ]])

Create a new `posixfile` object with the given *filename* and *mode*. The *filename*, *mode* and *bufsize* arguments are interpreted the same way as by the built-in `open()` function.

`posixfile.fileopen` (*fileobject*)

Create a new `posixfile` object with the given standard file object. The resulting object has the same *filename* and *mode* as the original file object.

The `posixfile` object defines the following additional methods:

`posixfile.lock` (*fmt* [, *len* [, *start* [, *whence* ] ] ])

Lock the specified section of the file that the file object is referring to. The format is explained below in a table. The *len* argument specifies the length of the section that should be locked. The default is 0. *start* specifies the starting offset of the section, where the default is 0. The *whence* argument specifies where the offset is relative to. It accepts one of the constants `SEEK_SET`, `SEEK_CUR` or `SEEK_END`. The default is `SEEK_SET`. For more information about the arguments refer to the `fcntl(2)` manual page on your system.

`posixfile.flags` (*flags* )

Set the specified flags for the file that the file object is referring to. The new flags are ORed with the old flags, unless specified otherwise. The format is explained below in a table. Without the *flags* argument a string indicating the current flags is returned (this is the same as the `?` modifier). For more information about the flags refer to the `fcntl(2)` manual page on your system.

`posixfile.dup` ()

Duplicate the file object and the underlying file pointer and file descriptor. The resulting object behaves as if it were newly opened.

`posixfile.dup2` (*fd*)

Duplicate the file object and the underlying file pointer and file descriptor. The new object will have the given file descriptor. Otherwise the resulting object behaves as if it were newly opened.

`posixfile.file` ()

Return the standard file object that the `posixfile` object is based on. This is sometimes necessary for functions that insist on a standard file object.

All methods raise `IOError` when the request fails.

Format characters for the `lock` () method have the following meaning:

Format	Meaning
u	unlock the specified region
r	request a read lock for the specified section
w	request a write lock for the specified section

In addition the following modifiers can be added to the format:

Modifier	Meaning	Notes
	wait until the lock has been granted	
?	return the first lock conflicting with the requested lock, or <code>None</code> if there is no conflict.	(1)

Note:

1. The lock returned is in the format (*mode*, *len*, *start*, *whence*, *pid*) where *mode* is a character representing the type of lock ('r' or 'w'). This modifier prevents a request from being granted; it is for query purposes only.

Format characters for the `flags` () method have the following meanings:

Format	Meaning
a	append only flag
c	close on exec flag
n	no delay flag (also called non-blocking flag)
s	synchronization flag

In addition the following modifiers can be added to the format:

Modifier	Meaning	Notes
!	turn the specified flags 'off', instead of the default 'on'	(1)
=	replace the flags, instead of the default 'OR' operation	(1)
?	return a string in which the characters represent the flags that are set.	(2)

Notes:

1. The ! and = modifiers are mutually exclusive.
2. This string represents the flags after they may have been altered by the same call.

Examples:

```
import posixfile

file = posixfile.open('/tmp/test', 'w')
file.lock('w|')
...
file.lock('u')
file.close()
```

## 35.13 resource — Resource usage information

*Platforms:* Unix

This module provides basic mechanisms for measuring and controlling system resources utilized by a program.

Symbolic constants are used to specify particular system resources and to request usage information about either the current process or its children.

A single exception is defined for errors:

**exception** `resource.error`

The functions described below may raise this error if the underlying system call failures unexpectedly.

### 35.13.1 Resource Limits

Resources usage can be limited using the `setrlimit()` function described below. Each resource is controlled by a pair of limits: a soft limit and a hard limit. The soft limit is the current limit, and may be lowered or raised by a process over time. The soft limit can never exceed the hard limit. The hard limit can be lowered to any value greater than the soft limit, but not raised. (Only processes with the effective UID of the super-user can raise a hard limit.)

The specific resources that can be limited are system dependent. They are described in the `getrlimit(2)` man page. The resources listed below are supported when the underlying operating system supports them; resources which cannot be checked or controlled by the operating system are not defined in this module for those platforms.

`resource.getrlimit(resource)`

Returns a tuple (soft, hard) with the current soft and hard limits of *resource*. Raises `ValueError` if an invalid resource is specified, or `error` if the underlying system call fails unexpectedly.

`resource.setrlimit(resource, limits)`

Sets new limits of consumption of *resource*. The *limits* argument must be a tuple (soft, hard) of two integers describing the new limits. A value of -1 can be used to specify the maximum possible upper limit.

Raises `ValueError` if an invalid resource is specified, if the new soft limit exceeds the hard limit, or if a process tries to raise its hard limit (unless the process has an effective UID of super-user). Can also raise `error` if the underlying system call fails.

These symbols define resources whose consumption can be controlled using the `setrlimit()` and `getrlimit()` functions described below. The values of these symbols are exactly the constants used by C programs.

The Unix man page for *getrlimit(2)* lists the available resources. Note that not all systems use the same symbol or same value to denote the same resource. This module does not attempt to mask platform differences — symbols not defined for a platform will not be available from this module on that platform.

`resource.RLIMIT_CORE`

The maximum size (in bytes) of a core file that the current process can create. This may result in the creation of a partial core file if a larger core would be required to contain the entire process image.

`resource.RLIMIT_CPU`

The maximum amount of processor time (in seconds) that a process can use. If this limit is exceeded, a SIGXCPU signal is sent to the process. (See the `signal` module documentation for information about how to catch this signal and do something useful, e.g. flush open files to disk.)

`resource.RLIMIT_FSIZE`

The maximum size of a file which the process may create. This only affects the stack of the main thread in a multi-threaded process.

`resource.RLIMIT_DATA`

The maximum size (in bytes) of the process's heap.

`resource.RLIMIT_STACK`

The maximum size (in bytes) of the call stack for the current process.

`resource.RLIMIT_RSS`

The maximum resident set size that should be made available to the process.

`resource.RLIMIT_NPROC`

The maximum number of processes the current process may create.

`resource.RLIMIT_NOFILE`

The maximum number of open file descriptors for the current process.

`resource.RLIMIT_OFILE`

The BSD name for `RLIMIT_NOFILE`.

`resource.RLIMIT_MEMLOCK`

The maximum address space which may be locked in memory.

`resource.RLIMIT_VMEM`

The largest area of mapped memory which the process may occupy.

`resource.RLIMIT_AS`

The maximum area (in bytes) of address space which may be taken by the process.

### 35.13.2 Resource Usage

These functions are used to retrieve resource usage information:

`resource.getrusage(who)`

This function returns an object that describes the resources consumed by either the current process or its children, as specified by the *who* parameter. The *who* parameter should be specified using one of the `RUSAGE_*` constants described below.

The fields of the return value each describe how a particular system resource has been used, e.g. amount of time spent running in user mode or number of times the process was swapped out of main memory. Some values are dependent on the clock tick interval, e.g. the amount of memory the process is using.

For backward compatibility, the return value is also accessible as a tuple of 16 elements.

The fields `ru_utime` and `ru_stime` of the return value are floating point values representing the amount of time spent executing in user mode and the amount of time spent executing in system mode, respectively. The

remaining values are integers. Consult the *getrusage(2)* man page for detailed information about these values. A brief summary is presented here:

Index	Field	Resource
0	ru_utime	time in user mode (float)
1	ru_stime	time in system mode (float)
2	ru_maxrss	maximum resident set size
3	ru_ixrss	shared memory size
4	ru_idrss	unshared memory size
5	ru_isrss	unshared stack size
6	ru_minflt	page faults not requiring I/O
7	ru_majflt	page faults requiring I/O
8	ru_nswap	number of swap outs
9	ru_inblock	block input operations
10	ru_oublock	block output operations
11	ru_msgsnd	messages sent
12	ru_msgrcv	messages received
13	ru_nsignals	signals received
14	ru_nvcsw	voluntary context switches
15	ru_nivcsw	involuntary context switches

This function will raise a `ValueError` if an invalid *who* parameter is specified. It may also raise `error` exception in unusual circumstances. Changed in version 2.3: Added access to values as attributes of the returned object.

`resource.getpagesize()`

Returns the number of bytes in a system page. (This need not be the same as the hardware page size.) This function is useful for determining the number of bytes of memory a process is using. The third element of the tuple returned by `getrusage()` describes memory usage in pages; multiplying by page size produces number of bytes.

The following `RUSAGE_*` symbols are passed to the `getrusage()` function to specify which processes information should be provided for.

`resource.RUSAGE_SELF`

`RUSAGE_SELF` should be used to request information pertaining only to the process itself.

`resource.RUSAGE_CHILDREN`

Pass to `getrusage()` to request resource information for child processes of the calling process.

`resource.RUSAGE_BOTH`

Pass to `getrusage()` to request resources consumed by both the current process and child processes. May not be available on all systems.

## 35.14 nis — Interface to Sun's NIS (Yellow Pages)

*Platforms:* Unix

The `nis` module gives a thin wrapper around the NIS library, useful for central administration of several hosts.

Because NIS exists only on Unix systems, this module is only available for Unix.

The `nis` module defines the following functions:

`nis.match(key, mapname[, domain=default_domain])`

Return the match for *key* in map *mapname*, or raise an error (`nis.error`) if there is none. Both should be strings, *key* is 8-bit clean. Return value is an arbitrary array of bytes (may contain `NULL` and other joys).

Note that *mapname* is first checked if it is an alias to another name. Changed in version 2.5: The *domain* argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

`nis.cat` (*mapname* [, *domain=default\_domain* ])

Return a dictionary mapping *key* to *value* such that `match(key, mapname)==value`. Note that both keys and values of the dictionary are arbitrary arrays of bytes.

Note that *mapname* is first checked if it is an alias to another name. Changed in version 2.5: The *domain* argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

`nis.maps` ([*domain=default\_domain* ])

Return a list of all valid maps. Changed in version 2.5: The *domain* argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

`nis.get_default_domain` ()

Return the system default NIS domain. New in version 2.5.

The `nis` module defines the following exception:

**exception** `nis.error`

An error raised when a NIS function returns an error code.

## 35.15 syslog — Unix syslog library routines

*Platforms:* Unix

This module provides an interface to the Unix `syslog` library routines. Refer to the Unix manual pages for a detailed description of the `syslog` facility.

This module wraps the system `syslog` family of routines. A pure Python library that can speak to a syslog server is available in the `logging.handlers` module as `SysLogHandler`.

The module defines the following functions:

`syslog.syslog` (*message*)

`syslog.syslog` (*priority, message*)

Send the string *message* to the system logger. A trailing newline is added if necessary. Each message is tagged with a priority composed of a *facility* and a *level*. The optional *priority* argument, which defaults to `LOG_INFO`, determines the message priority. If the facility is not encoded in *priority* using logical-or (`LOG_INFO | LOG_USER`), the value given in the `openlog` () call is used.

If `openlog` () has not been called prior to the call to `syslog` (), `openlog` () will be called with no arguments.

`syslog.openlog` ([*ident* [, *logoption* [, *facility* ] ] ])

Logging options of subsequent `syslog` () calls can be set by calling `openlog` (). `syslog` () will call `openlog` () with no arguments if the log is not currently open.

The optional *ident* keyword argument is a string which is prepended to every message, and defaults to `sys.argv[0]` with leading path components stripped. The optional *logoption* keyword argument (default is 0) is a bit field – see below for possible values to combine. The optional *facility* keyword argument (default is `LOG_USER`) sets the default facility for messages which do not have a facility explicitly encoded.

`syslog.closelog` ()

Reset the `syslog` module values and call the system library `closelog` () .

This causes the module to behave as it does when initially imported. For example, `openlog()` will be called on the first `syslog()` call (if `openlog()` hasn't already been called), and `ident` and other `openlog()` parameters are reset to defaults.

`syslog.setlogmask(maskpri)`

Set the priority mask to `maskpri` and return the previous mask value. Calls to `syslog()` with a priority level not set in `maskpri` are ignored. The default is to log all priorities. The function `LOG_MASK(pri)` calculates the mask for the individual priority `pri`. The function `LOG_UPTO(pri)` calculates the mask for all priorities up to and including `pri`.

The module defines the following constants:

**Priority levels (high to low):** `LOG_EMERG`, `LOG_ALERT`, `LOG_CRIT`, `LOG_ERR`, `LOG_WARNING`, `LOG_NOTICE`, `LOG_INFO`, `LOG_DEBUG`.

**Facilities:** `LOG_KERN`, `LOG_USER`, `LOG_MAIL`, `LOG_DAEMON`, `LOG_AUTH`, `LOG_LPR`, `LOG_NEWS`, `LOG_UUCP`, `LOG_CRON`, `LOG_SYSLOG` and `LOG_LOCAL0` to `LOG_LOCAL7`.

**Log options:** `LOG_PID`, `LOG_CONS`, `LOG_NDELAY`, `LOG_NOWAIT` and `LOG_PERROR` if defined in `<syslog.h>`.

## 35.15.1 Examples

### Simple example

A simple set of examples:

```
import syslog
```

```
syslog.syslog('Processing started')
if error:
    syslog.syslog(syslog.LOG_ERR, 'Processing started')
```

An example of setting some log options, these would include the process ID in logged messages, and write the messages to the destination facility used for mail logging:

```
syslog.openlog(logoption=syslog.LOG_PID, facility=syslog.LOG_MAIL)
syslog.syslog('E-mail processing initiated...')
```

## 35.16 commands — Utilities for running commands

*Platforms:* Unix

Deprecated since version 2.6: The `commands` module has been removed in Python 3. Use the `subprocess` module instead. The `commands` module contains wrapper functions for `os.popen()` which take a system command as a string and return any output generated by the command and, optionally, the exit status.

The `subprocess` module provides more powerful facilities for spawning new processes and retrieving their results. Using the `subprocess` module is preferable to using the `commands` module.

---

**Note:** In Python 3.x, `getstatus()` and two undocumented functions (`mk2arg()` and `mkarg()`) have been removed. Also, `getstatusoutput()` and `getoutput()` have been moved to the `subprocess` module.

---

The `commands` module defines the following functions:

`commands.getstatusoutput` (*cmd*)

Execute the string *cmd* in a shell with `os.popen()` and return a 2-tuple (*status*, *output*). *cmd* is actually run as `{ cmd ; } 2>&1`, so that the returned output will contain output or error messages. A trailing newline is stripped from the output. The exit status for the command can be interpreted according to the rules for the C function `wait()`.

`commands.getoutput` (*cmd*)

Like `getstatusoutput()`, except the exit status is ignored and the return value is a string containing the command's output.

`commands.getstatus` (*file*)

Return the output of `ls -ld file` as a string. This function uses the `getoutput()` function, and properly escapes backslashes and dollar signs in the argument. Deprecated since version 2.6: This function is nonobvious and useless. The name is also misleading in the presence of `getstatusoutput()`.

Example:

```
>>> import commands
>>> commands.getstatusoutput('ls /bin/ls')
(0, '/bin/ls')
>>> commands.getstatusoutput('cat /bin/junk')
(256, 'cat: /bin/junk: No such file or directory')
>>> commands.getstatusoutput('/bin/junk')
(256, 'sh: /bin/junk: not found')
>>> commands.getoutput('ls /bin/ls')
'/bin/ls'
>>> commands.getstatus('/bin/ls')
'-rwxr-xr-x 1 root          13352 Oct 14  1994 /bin/ls'
```

**See Also:**

**Module `subprocess`** Module for spawning and managing subprocesses.

# MAC OS X SPECIFIC SERVICES

This chapter describes modules that are only available on the Mac OS X platform.

See the chapters *MacPython OSA Modules* and *Undocumented Mac OS modules* for more modules, and the HOWTO *using-on-mac* for a general introduction to Mac-specific Python programming.

---

**Note:** These modules are deprecated and have been removed in Python 3.x.

---

## 36.1 `ic` — Access to the Mac OS X Internet Config

*Platforms:* Mac

This module provides access to various internet-related preferences set through **System Preferences** or the **Finder**.

---

**Note:** This module has been removed in Python 3.x.

---

There is a low-level companion module `icglue` which provides the basic Internet Config access functionality. This low-level module is not documented, but the docstrings of the routines document the parameters and the routine names are the same as for the Pascal or C API to Internet Config, so the standard IC programmers' documentation can be used if this module is needed.

The `ic` module defines the `error` exception and symbolic names for all error codes Internet Config can produce; see the source for details.

### exception `ic.error`

Exception raised on errors in the `ic` module.

The `ic` module defines the following class and function:

**class** `ic.IC` (`[signature`, `ic` ])

Create an Internet Config object. The signature is a 4-character creator code of the current application (default 'Pyth') which may influence some of ICs settings. The optional `ic` argument is a low-level `icglue.icinstance` created beforehand, this may be useful if you want to get preferences from a different config file, etc.

`ic.launchurl` (`url`, `hint` )

`ic.parseurl` (`data`, `start`, `end`, `hint` ] ])

`ic.mapfile` (`file`)

`ic.maptypescreator` (`type`, `creator`, `filename` ])

`ic.settypescreator` (`file`)

These functions are “shortcuts” to the methods of the same name, described below.

### 36.1.1 IC Objects

IC objects have a mapping interface, hence to obtain the mail address you simply get `ic['MailAddress']`. Assignment also works, and changes the option in the configuration file.

The module knows about various datatypes, and converts the internal IC representation to a “logical” Python data structure. Running the `ic` module standalone will run a test program that lists all keys and values in your IC database, this will have to serve as documentation.

If the module does not know how to represent the data it returns an instance of the `ICOpaqueData` type, with the raw data in its `data` attribute. Objects of this type are also acceptable values for assignment.

Besides the dictionary interface, IC objects have the following methods:

IC.**launchurl** (*url* [, *hint* ])

Parse the given URL, launch the correct application and pass it the URL. The optional *hint* can be a scheme name such as `'mailto:'`, in which case incomplete URLs are completed with this scheme. If *hint* is not provided, incomplete URLs are invalid.

IC.**parseurl** (*data* [, *start* [, *end* [, *hint* ] ] ])

Find an URL somewhere in *data* and return start position, end position and the URL. The optional *start* and *end* can be used to limit the search, so for instance if a user clicks in a long text field you can pass the whole text field and the click-position in *start* and this routine will return the whole URL in which the user clicked. As above, *hint* is an optional scheme used to complete incomplete URLs.

IC.**mapfile** (*file*)

Return the mapping entry for the given *file*, which can be passed as either a filename or an `FSSpec()` result, and which need not exist.

The mapping entry is returned as a tuple (*version*, *type*, *creator*, *postcreator*, *flags*, *extension*, *appname*, *postappname*, *mimetype*, *entryname*), where *version* is the entry version number, *type* is the 4-character filetype, *creator* is the 4-character creator type, *postcreator* is the 4-character creator code of an optional application to post-process the file after downloading, *flags* are various bits specifying whether to transfer in binary or ascii and such, *extension* is the filename extension for this file type, *appname* is the printable name of the application to which this file belongs, *postappname* is the name of the postprocessing application, *mimetype* is the MIME type of this file and *entryname* is the name of this entry.

IC.**maptypecreator** (*type*, *creator* [, *filename* ])

Return the mapping entry for files with given 4-character *type* and *creator* codes. The optional *filename* may be specified to further help finding the correct entry (if the creator code is `'????'`, for instance).

The mapping entry is returned in the same format as for *mapfile*.

IC.**settypecreator** (*file*)

Given an existing *file*, specified either as a filename or as an `FSSpec()` result, set its creator and type correctly based on its extension. The finder is told about the change, so the finder icon will be updated quickly.

## 36.2 MacOS — Access to Mac OS interpreter features

*Platforms:* Mac

This module provides access to MacOS specific functionality in the Python interpreter, such as how the interpreter eventloop functions and the like. Use with care.

---

**Note:** This module has been removed in Python 3.x.

---

Note the capitalization of the module name; this is a historical artifact.

**MacOS.runtimeModel**

Always 'macho', from Python 2.4 on. In earlier versions of Python the value could also be 'ppc' for the classic Mac OS 8 runtime model or 'carbon' for the Mac OS 9 runtime model.

**MacOS.linkModel**

The way the interpreter has been linked. As extension modules may be incompatible between linking models, packages could use this information to give more decent error messages. The value is one of 'static' for a statically linked Python, 'framework' for Python in a Mac OS X framework, 'shared' for Python in a standard Unix shared library. Older Pythons could also have the value 'cfm' for Mac OS 9-compatible Python.

**exception MacOS.Error**

This exception is raised on MacOS generated errors, either from functions in this module or from other mac-specific modules like the toolbox interfaces. The arguments are the integer error code (the `OSERR` value) and a textual description of the error code. Symbolic names for all known error codes are defined in the standard module `macerrors`.

**MacOS.GetErrorString** (*errno*)

Return the textual description of MacOS error code *errno*.

**MacOS.DebugStr** (*message* [, *object* ])

On Mac OS X the string is simply printed to stderr (on older Mac OS systems more elaborate functionality was available), but it provides a convenient location to attach a breakpoint in a low-level debugger like **gdb**.

---

**Note:** Not available in 64-bit mode.

---

**MacOS.SysBeep** ()

Ring the bell.

---

**Note:** Not available in 64-bit mode.

---

**MacOS.GetTicks** ()

Get the number of clock ticks (1/60th of a second) since system boot.

**MacOS.GetCreatorAndType** (*file*)

Return the file creator and file type as two four-character strings. The *file* parameter can be a pathname or an `FSSpec` or `FSRef` object.

---

**Note:** It is not possible to use an `FSSpec` in 64-bit mode.

---

**MacOS.SetCreatorAndType** (*file*, *creator*, *type*)

Set the file creator and file type. The *file* parameter can be a pathname or an `FSSpec` or `FSRef` object. *creator* and *type* must be four character strings.

---

**Note:** It is not possible to use an `FSSpec` in 64-bit mode.

---

**MacOS.openrf** (*name* [, *mode* ])

Open the resource fork of a file. Arguments are the same as for the built-in function `open()`. The object returned has file-like semantics, but it is not a Python file object, so there may be subtle differences.

**MacOS.WMAvailable** ()

Checks whether the current process has access to the window manager. The method will return `False` if the window manager is not available, for instance when running on Mac OS X Server or when logged in via ssh, or when the current interpreter is not running from a fullblown application bundle. A script runs from

an application bundle either when it has been started with **pythonw** instead of **python** or when running as an applet.

MacOS. **splash** (*[resourceid]*)

Opens a splash screen by resource id. Use resourceid 0 to close the splash screen.

---

**Note:** Not available in 64-bit mode.

---

## 36.3 macostools — Convenience routines for file manipulation

*Platforms:* Mac

This module contains some convenience routines for file-manipulation on the Macintosh. All file parameters can be specified as pathnames, FSRef or FSSpec objects. This module expects a filesystem which supports forked files, so it should not be used on UFS partitions.

---

**Note:** This module has been removed in Python 3.

---

The `macostools` module defines the following functions:

`macostools.copy` (*src, dst* [*, createpath* [*, copytimes* ] ])

Copy file *src* to *dst*. If *createpath* is non-zero the folders leading to *dst* are created if necessary. The method copies data and resource fork and some finder information (creator, type, flags) and optionally the creation, modification and backup times (default is to copy them). Custom icons, comments and icon position are not copied.

---

**Note:** This function does not work in 64-bit code because it uses APIs that are not available in 64-bit mode.

---

`macostools.copytree` (*src, dst*)

Recursively copy a file tree from *src* to *dst*, creating folders as needed. *src* and *dst* should be specified as pathnames.

---

**Note:** This function does not work in 64-bit code because it uses APIs that are not available in 64-bit mode.

---

`macostools.mkalias` (*src, dst*)

Create a finder alias *dst* pointing to *src*.

---

**Note:** This function does not work in 64-bit code because it uses APIs that are not available in 64-bit mode.

---

`macostools.touched` (*dst*)

Tell the finder that some bits of finder-information such as creator or type for file *dst* has changed. The file can be specified by pathname or fsspec. This call should tell the finder to redraw the files icon. Deprecated since version 2.6: The function is a no-op on OS X.

`macostools.BUFSIZ`

The buffer size for `copy`, default 1 megabyte.

Note that the process of creating finder aliases is not specified in the Apple documentation. Hence, aliases created with `mkalias()` could conceivably have incompatible behaviour in some cases.

## 36.4 findertools — The finder’s Apple Events interface

*Platforms:* Mac

This module contains routines that give Python programs access to some functionality provided by the finder. They are implemented as wrappers around the AppleEvent interface to the finder.

All file and folder parameters can be specified either as full pathnames, or as `FSRef` or `FSSpec` objects.

The `findertools` module defines the following functions:

`findertools.launch(file)`

Tell the finder to launch *file*. What launching means depends on the file: applications are started, folders are opened and documents are opened in the correct application.

`findertools.Print(file)`

Tell the finder to print a file. The behaviour is identical to selecting the file and using the print command in the finder’s file menu.

`findertools.copy(file, destdir)`

Tell the finder to copy a file or folder *file* to folder *destdir*. The function returns an `Alias` object pointing to the new file.

`findertools.move(file, destdir)`

Tell the finder to move a file or folder *file* to folder *destdir*. The function returns an `Alias` object pointing to the new file.

`findertools.sleep()`

Tell the finder to put the Macintosh to sleep, if your machine supports it.

`findertools.restart()`

Tell the finder to perform an orderly restart of the machine.

`findertools.shutdown()`

Tell the finder to perform an orderly shutdown of the machine.

## 36.5 EasyDialogs — Basic Macintosh dialogs

*Platforms:* Mac

The `EasyDialogs` module contains some simple dialogs for the Macintosh. The dialogs get launched in a separate application which appears in the dock and must be clicked on for the dialogs be displayed. All routines take an optional resource ID parameter *id* with which one can override the `DLOG` resource used for the dialog, provided that the dialog items correspond (both type and item number) to those in the default `DLOG` resource. See source code for details.

---

**Note:** This module has been removed in Python 3.x.

---

The `EasyDialogs` module defines the following functions:

`EasyDialogs.Message(str[, id[, ok]])`

Displays a modal dialog with the message text *str*, which should be at most 255 characters long. The button text defaults to “OK”, but is set to the string argument *ok* if the latter is supplied. Control is returned when the user clicks the “OK” button.

`EasyDialogs.AskString(prompt[, default[, id[, ok[, cancel]]]])`

Asks the user to input a string value via a modal dialog. *prompt* is the prompt message, and the optional *default* supplies the initial value for the string (otherwise “ ” is used). The text of the “OK” and “Cancel” buttons can be

changed with the *ok* and *cancel* arguments. All strings can be at most 255 bytes long. `AskString()` returns the string entered or `None` in case the user cancelled.

`EasyDialogs.AskPassword(prompt[, default[, id[, ok[, cancel]]]])`

Asks the user to input a string value via a modal dialog. Like `AskString()`, but with the text shown as bullets. The arguments have the same meaning as for `AskString()`.

`EasyDialogs.AskYesNoCancel(question[, default[, yes[, no[, cancel[, id]]]])`

Presents a dialog with prompt *question* and three buttons labelled “Yes”, “No”, and “Cancel”. Returns 1 for “Yes”, 0 for “No” and -1 for “Cancel”. The value of *default* (or 0 if *default* is not supplied) is returned when the RETURN key is pressed. The text of the buttons can be changed with the *yes*, *no*, and *cancel* arguments; to prevent a button from appearing, supply "" for the corresponding argument.

`EasyDialogs.ProgressBar([title[, maxval[, label[, id]]]])`

Displays a modeless progress-bar dialog. This is the constructor for the `ProgressBar` class described below. *title* is the text string displayed (default “Working...”), *maxval* is the value at which progress is complete (default 0, indicating that an indeterminate amount of work remains to be done), and *label* is the text that is displayed above the progress bar itself.

`EasyDialogs.GetArgv([optionlist[ commandlist[, addoldfile[, addnewfile[, addfolder[, id]]]])`

Displays a dialog which aids the user in constructing a command-line argument list. Returns the list in `sys.argv` format, suitable for passing as an argument to `getopt.getopt()`. *addoldfile*, *addnewfile*, and *addfolder* are boolean arguments. When nonzero, they enable the user to insert into the command line paths to an existing file, a (possibly) not-yet-existent file, and a folder, respectively. (Note: Option arguments must appear in the command line before file and folder arguments in order to be recognized by `getopt.getopt()`.) Arguments containing spaces can be specified by enclosing them within single or double quotes. A `SystemExit` exception is raised if the user presses the “Cancel” button.

*optionlist* is a list that determines a popup menu from which the allowed options are selected. Its items can take one of two forms: *optstr* or (*optstr*, *descr*). When present, *descr* is a short descriptive string that is displayed in the dialog while this option is selected in the popup menu. The correspondence between *optstrs* and command-line arguments is:

<i>optstr</i> format	Command-line format
x	-x (short option)
x: or x=	-x (short option with value)
xyz	--xyz (long option)
xyz: or xyz=	--xyz (long option with value)

*commandlist* is a list of items of the form *cmdstr* or (*cmdstr*, *descr*), where *descr* is as above. The *cmdstrs* will appear in a popup menu. When chosen, the text of *cmdstr* will be appended to the command line as is, except that a trailing ':' or '=' (if present) will be trimmed off. New in version 2.0.

`EasyDialogs.AskFileForOpen([message] [, typeList] [, defaultLocation] [, defaultOptionFlags] [, location] [, clientName] [, windowTitle] [, actionButtonLabel] [, cancelButtonLabel] [, preferenceKey] [, popupExtension] [, eventProc] [, previewProc] [, filterProc] [, wanted] )`

Post a dialog asking the user for a file to open, and return the file selected or `None` if the user cancelled. *message* is a text message to display, *typeList* is a list of 4-char filetypes allowable, *defaultLocation* is the pathname, `FSSpec` or `FSRef` of the folder to show initially, *location* is the (*x*, *y*) position on the screen where the dialog is shown, *actionButtonLabel* is a string to show instead of “Open” in the OK button, *cancelButtonLabel* is a string to show instead of “Cancel” in the cancel button, *wanted* is the type of value wanted as a return: `str`, `unicode`, `FSSpec`, `FSRef` and subtypes thereof are acceptable.

For a description of the other arguments please see the Apple Navigation Services documentation and the `EasyDialogs` source code.

`EasyDialogs.AskFileForSave` ( *[message]* [, *savedFileName*] [, *defaultLocation*] [, *defaultOptionFlags*] [, *location*] [, *clientName*] [, *windowTitle*] [, *actionButtonLabel*] [, *cancelButtonLabel*] [, *preferenceKey*] [, *popupExtension*] [, *fileType*] [, *fileCreator*] [, *eventProc*] [, *wanted*] )

Post a dialog asking the user for a file to save to, and return the file selected or `None` if the user cancelled. *savedFileName* is the default for the file name to save to (the return value). See `AskFileForOpen()` for a description of the other arguments.

`EasyDialogs.AskFolder` ( *[message]* [, *defaultLocation*] [, *defaultOptionFlags*] [, *location*] [, *clientName*] [, *windowTitle*] [, *actionButtonLabel*] [, *cancelButtonLabel*] [, *preferenceKey*] [, *popupExtension*] [, *eventProc*] [, *filterProc*] [, *wanted*] )

Post a dialog asking the user to select a folder, and return the folder selected or `None` if the user cancelled. See `AskFileForOpen()` for a description of the arguments.

#### See Also:

**Navigation Services Reference** Programmer’s reference documentation for the Navigation Services, a part of the Carbon framework.

### 36.5.1 ProgressBar Objects

`ProgressBar` objects provide support for modeless progress-bar dialogs. Both determinate (thermometer style) and indeterminate (barber-pole style) progress bars are supported. The bar will be determinate if its maximum value is greater than zero; otherwise it will be indeterminate. Changed in version 2.2: Support for indeterminate-style progress bars was added. The dialog is displayed immediately after creation. If the dialog’s “Cancel” button is pressed, or if `Cmd-` or `ESC` is typed, the dialog window is hidden and `KeyboardInterrupt` is raised (but note that this response does not occur until the progress bar is next updated, typically via a call to `inc()` or `set()`). Otherwise, the bar remains visible until the `ProgressBar` object is discarded.

`ProgressBar` objects possess the following attributes and methods:

`ProgressBar.curval`

The current value (of type integer or long integer) of the progress bar. The normal access methods coerce `curval` between 0 and `maxval`. This attribute should not be altered directly.

`ProgressBar.maxval`

The maximum value (of type integer or long integer) of the progress bar; the progress bar (thermometer style) is full when `curval` equals `maxval`. If `maxval` is 0, the bar will be indeterminate (barber-pole). This attribute should not be altered directly.

`ProgressBar.title` (*[newstr]*)

Sets the text in the title bar of the progress dialog to *newstr*.

`ProgressBar.label` (*[newstr]*)

Sets the text in the progress box of the progress dialog to *newstr*.

`ProgressBar.set` (*value* [, *max*])

Sets the progress bar’s `curval` to *value*, and also `maxval` to *max* if the latter is provided. *value* is first coerced between 0 and `maxval`. The thermometer bar is updated to reflect the changes, including a change from indeterminate to determinate or vice versa.

`ProgressBar.inc` (*[n]*)

Increments the progress bar’s `curval` by *n*, or by 1 if *n* is not provided. (Note that *n* may be negative, in which case the effect is a decrement.) The progress bar is updated to reflect the change. If the bar is indeterminate, this causes one “spin” of the barber pole. The resulting `curval` is coerced between 0 and `maxval` if incrementing causes it to fall outside this range.

## 36.6 FrameWork — Interactive application framework

*Platforms:* Mac

The `FrameWork` module contains classes that together provide a framework for an interactive Macintosh application. The programmer builds an application by creating subclasses that override various methods of the bases classes, thereby implementing the functionality wanted. Overriding functionality can often be done on various different levels, i.e. to handle clicks in a single dialog window in a non-standard way it is not necessary to override the complete event handling.

---

**Note:** This module has been removed in Python 3.x.

---

Work on the `FrameWork` has pretty much stopped, now that `PyObjC` is available for full Cocoa access from Python, and the documentation describes only the most important functionality, and not in the most logical manner at that. Examine the source or the examples for more details. The following are some comments posted on the MacPython newsgroup about the strengths and limitations of `FrameWork`:

The strong point of `FrameWork` is that it allows you to break into the control-flow at many different places. `W`, for instance, uses a different way to enable/disable menus and that plugs right in leaving the rest intact. The weak points of `FrameWork` are that it has no abstract command interface (but that shouldn't be difficult), that its dialog support is minimal and that its control/toolbar support is non-existent.

The `FrameWork` module defines the following functions:

`FrameWork.Application()`

An object representing the complete application. See below for a description of the methods. The default `__init__()` routine creates an empty window dictionary and a menu bar with an apple menu.

`FrameWork.MenuBar()`

An object representing the menubar. This object is usually not created by the user.

`FrameWork.Menu(bar, title[, after])`

An object representing a menu. Upon creation you pass the `MenuBar` the menu appears in, the *title* string and a position (1-based) *after* where the menu should appear (default: at the end).

`FrameWork.MenuItem(menu, title[, shortcut, callback])`

Create a menu item object. The arguments are the menu to create, the item title string and optionally the keyboard shortcut and a callback routine. The callback is called with the arguments menu-id, item number within menu (1-based), current front window and the event record.

Instead of a callable object the callback can also be a string. In this case menu selection causes the lookup of a method in the topmost window and the application. The method name is the callback string with `'domenu_'` prepended.

Calling the `MenuBar fixmenudimstate()` method sets the correct dimming for all menu items based on the current front window.

`FrameWork.Separator(menu)`

Add a separator to the end of a menu.

`FrameWork.SubMenu(menu, label)`

Create a submenu named *label* under menu *menu*. The menu object is returned.

`FrameWork.Window(parent)`

Creates a (modeless) window. *Parent* is the application object to which the window belongs. The window is not displayed until later.

`FrameWork.DialogWindow(parent)`

Creates a modeless dialog window.

`FrameWork.windowbounds` (*width, height*)

Return a (*left, top, right, bottom*) tuple suitable for creation of a window of given width and height. The window will be staggered with respect to previous windows, and an attempt is made to keep the whole window on-screen. However, the window will however always be the exact size given, so parts may be offscreen.

`FrameWork.setwatchcursor` ()

Set the mouse cursor to a watch.

`FrameWork.setarrowcursor` ()

Set the mouse cursor to an arrow.

### 36.6.1 Application Objects

Application objects have the following methods, among others:

`Application.makeusermenus` ()

Override this method if you need menus in your application. Append the menus to the attribute `menubar`.

`Application.getabouttext` ()

Override this method to return a text string describing your application. Alternatively, override the `do_about` () method for more elaborate “about” messages.

`Application.mainloop` (*[mask[, wait ]]*)

This routine is the main event loop, call it to set your application rolling. *Mask* is the mask of events you want to handle, *wait* is the number of ticks you want to leave to other concurrent application (default 0, which is probably not a good idea). While raising *self* to exit the mainloop is still supported it is not recommended: call `self._quit` () instead.

The event loop is split into many small parts, each of which can be overridden. The default methods take care of dispatching events to windows and dialogs, handling drags and resizes, Apple Events, events for non-FrameWork windows, etc.

In general, all event handlers should return 1 if the event is fully handled and 0 otherwise (because the front window was not a FrameWork window, for instance). This is needed so that update events and such can be passed on to other windows like the Sioux console window. Calling `MacOS.HandleEvent` () is not allowed within *our\_dispatch* or its callees, since this may result in an infinite loop if the code is called through the Python inner-loop event handler.

`Application.asyncevents` (*onoff*)

Call this method with a nonzero parameter to enable asynchronous event handling. This will tell the inner interpreter loop to call the application event handler *async\_dispatch* whenever events are available. This will cause FrameWork window updates and the user interface to remain working during long computations, but will slow the interpreter down and may cause surprising results in non-reentrant code (such as FrameWork itself). By default *async\_dispatch* will immediately call *our\_dispatch* but you may override this to handle only certain events asynchronously. Events you do not handle will be passed to Sioux and such.

The old on/off value is returned.

`Application._quit` ()

Terminate the running `mainloop` () call at the next convenient moment.

`Application.do_char` (*c, event*)

The user typed character *c*. The complete details of the event can be found in the *event* structure. This method can also be provided in a `Window` object, which overrides the application-wide handler if the window is front-most.

`Application.do_dialogevent` (*event*)

Called early in the event loop to handle modeless dialog events. The default method simply dispatches the event

to the relevant dialog (not through the `DialogWindow` object involved). Override if you need special handling of dialog events (keyboard shortcuts, etc).

`Application.idle(event)`

Called by the main event loop when no events are available. The null-event is passed (so you can look at mouse position, etc).

## 36.6.2 Window Objects

Window objects have the following methods, among others:

`Window.open()`

Override this method to open a window. Store the Mac OS window-id in `self.wid` and call the `do_postopen()` method to register the window with the parent application.

`Window.close()`

Override this method to do any special processing on window close. Call the `do_postclose()` method to cleanup the parent state.

`Window.do_postresize(width, height, macoswindowid)`

Called after the window is resized. Override if more needs to be done than calling `InvalRect`.

`Window.do_contentclick(local, modifiers, event)`

The user clicked in the content part of a window. The arguments are the coordinates (window-relative), the key modifiers and the raw event.

`Window.do_update(macoswindowid, event)`

An update event for the window was received. Redraw the window.

`Window.do_activate(activate, event)`

The window was activated (`activate == 1`) or deactivated (`activate == 0`). Handle things like focus highlighting, etc.

## 36.6.3 ControlsWindow Object

`ControlsWindow` objects have the following methods besides those of `Window` objects:

`ControlsWindow.do_controlhit(window, control, pcode, event)`

Part `pcode` of control `control` was hit by the user. Tracking and such has already been taken care of.

## 36.6.4 ScrolledWindow Object

`ScrolledWindow` objects are `ControlsWindow` objects with the following extra methods:

`ScrolledWindow.scrollbars([wantx[, wanty]])`

Create (or destroy) horizontal and vertical scrollbars. The arguments specify which you want (default: both). The scrollbars always have minimum 0 and maximum 32767.

`ScrolledWindow.getscrollbarvalues()`

You must supply this method. It should return a tuple (`x`, `y`) giving the current position of the scrollbars (between 0 and 32767). You can return `None` for either to indicate the whole document is visible in that direction.

`ScrolledWindow.updatescrollbars()`

Call this method when the document has changed. It will call `getscrollbarvalues()` and update the scrollbars.

ScrolledWindow.**scrollbar\_callback** (*which, what, value*)

Supplied by you and called after user interaction. *which* will be 'x' or 'y', *what* will be '-', '--', 'set', '++' or '+'. For 'set', *value* will contain the new scrollbar position.

ScrolledWindow.**scalebarvalues** (*absmin, absmax, curmin, curmax*)

Auxiliary method to help you calculate values to return from `getscrollbarvalues()`. You pass document minimum and maximum value and topmost (leftmost) and bottommost (rightmost) visible values and it returns the correct number or None.

ScrolledWindow.**do\_activate** (*onoff, event*)

Takes care of dimming/highlighting scrollbars when a window becomes frontmost. If you override this method, call this one at the end of your method.

ScrolledWindow.**do\_postresize** (*width, height, window*)

Moves scrollbars to the correct position. Call this method initially if you override it.

ScrolledWindow.**do\_controlhit** (*window, control, pcode, event*)

Handles scrollbar interaction. If you override it call this method first, a nonzero return value indicates the hit was in the scrollbars and has been handled.

## 36.6.5 DialogWindow Objects

DialogWindow objects have the following methods besides those of Window objects:

DialogWindow.**open** (*resid*)

Create the dialog window, from the DLOG resource with id *resid*. The dialog object is stored in `self.wid`.

DialogWindow.**do\_itemhit** (*item, event*)

Item number *item* was hit. You are responsible for redrawing toggle buttons, etc.

## 36.7 autoGIL — Global Interpreter Lock handling in event loops

*Platforms:* Mac

The `autoGIL` module provides a function `installAutoGIL()` that automatically locks and unlocks Python's *Global Interpreter Lock* when running an event loop.

---

**Note:** This module has been removed in Python 3.x.

---

**exception** `autoGIL.AutoGILError`

Raised if the observer callback cannot be installed, for example because the current thread does not have a run loop.

`autoGIL.installAutoGIL()`

Install an observer callback in the event loop (`CFRunLoop`) for the current thread, that will lock and unlock the Global Interpreter Lock (GIL) at appropriate times, allowing other Python threads to run while the event loop is idle.

Availability: OSX 10.1 or later.

## 36.8 Mac OS Toolbox Modules

There are a set of modules that provide interfaces to various Mac OS toolboxes. If applicable the module will define a number of Python objects for the various structures declared by the toolbox, and operations will be implemented as

methods of the object. Other operations will be implemented as functions in the module. Not all operations possible in C will also be possible in Python (callbacks are often a problem), and parameters will occasionally be different in Python (input and output buffers, especially). All methods and functions have a `__doc__` string describing their arguments and return values, and for additional description you are referred to [Inside Macintosh](#) or similar works.

These modules all live in a package called `Carbon`. Despite that name they are not all part of the Carbon framework: CF is really in the CoreFoundation framework and Qt is in the QuickTime framework. The normal use pattern is

```
from Carbon import AE
```

---

**Note:** The Carbon modules have been removed in Python 3.

---

### 36.8.1 `Carbon.AE` — Apple Events

*Platforms:* Mac

### 36.8.2 `Carbon.AH` — Apple Help

*Platforms:* Mac

### 36.8.3 `Carbon.App` — Appearance Manager

*Platforms:* Mac

### 36.8.4 `Carbon.Appearance` — Appearance Manager constants

*Platforms:* Mac

### 36.8.5 `Carbon.CF` — Core Foundation

*Platforms:* Mac

The `CFBase`, `CFArray`, `CFData`, `CFDictionary`, `CFString` and `CFURL` objects are supported, some only partially.

### 36.8.6 `Carbon.CG` — Core Graphics

*Platforms:* Mac

### 36.8.7 `Carbon.CarbonEvt` — Carbon Event Manager

*Platforms:* Mac

### 36.8.8 `Carbon.CarbonEvents` — Carbon Event Manager constants

*Platforms:* Mac

### **36.8.9 Carbon.Cm — Component Manager**

*Platforms:* Mac

### **36.8.10 Carbon.Components — Component Manager constants**

*Platforms:* Mac

### **36.8.11 Carbon.ControlAccessor — Control Manager accssors**

*Platforms:* Mac

### **36.8.12 Carbon.Controls — Control Manager constants**

*Platforms:* Mac

### **36.8.13 Carbon.CoreFounation — CoreFounation constants**

*Platforms:* Mac

### **36.8.14 Carbon.CoreGraphics — CoreGraphics constants**

*Platforms:* Mac

### **36.8.15 Carbon.Ctl — Control Manager**

*Platforms:* Mac

### **36.8.16 Carbon.Dialogs — Dialog Manager constants**

*Platforms:* Mac

### **36.8.17 Carbon.Dlg — Dialog Manager**

*Platforms:* Mac

### **36.8.18 Carbon.Drag — Drag and Drop Manager**

*Platforms:* Mac

### **36.8.19 Carbon.Dragconst — Drag and Drop Manager constants**

*Platforms:* Mac

### **36.8.20 Carbon.Events — Event Manager constants**

*Platforms:* Mac

### **36.8.21 Carbon.Evt — Event Manager**

*Platforms:* Mac

### **36.8.22 Carbon.File — File Manager**

*Platforms:* Mac

### **36.8.23 Carbon.Files — File Manager constants**

*Platforms:* Mac

### **36.8.24 Carbon.Fm — Font Manager**

*Platforms:* Mac

### **36.8.25 Carbon.Folder — Folder Manager**

*Platforms:* Mac

### **36.8.26 Carbon.Folders — Folder Manager constants**

*Platforms:* Mac

### **36.8.27 Carbon.Fonts — Font Manager constants**

*Platforms:* Mac

### **36.8.28 Carbon.Help — Help Manager**

*Platforms:* Mac

### **36.8.29 Carbon.IBCarbon — Carbon InterfaceBuilder**

*Platforms:* Mac

### **36.8.30 Carbon.IBCarbonRuntime — Carbon InterfaceBuilder constants**

*Platforms:* Mac

### **36.8.31 Carbon.Icn — Carbon Icon Manager**

*Platforms:* Mac

### **36.8.32 Carbon.Icons — Carbon Icon Manager constants**

*Platforms:* Mac

### **36.8.33 Carbon.Launch — Carbon Launch Services**

*Platforms:* Mac

### **36.8.34 Carbon.LaunchServices — Carbon Launch Services constants**

*Platforms:* Mac

### **36.8.35 Carbon.List — List Manager**

*Platforms:* Mac

### **36.8.36 Carbon.Lists — List Manager constants**

*Platforms:* Mac

### **36.8.37 Carbon.MacHelp — Help Manager constants**

*Platforms:* Mac

### **36.8.38 Carbon.MediaDescr — Parsers and generators for Quicktime Media descriptors**

*Platforms:* Mac

### **36.8.39 Carbon.Menu — Menu Manager**

*Platforms:* Mac

### **36.8.40 Carbon.Menus — Menu Manager constants**

*Platforms:* Mac

### **36.8.41 Carbon.Mlte — MultiLingual Text Editor**

*Platforms:* Mac

### **36.8.42 Carbon.OSA — Carbon OSA Interface**

*Platforms:* Mac

### **36.8.43 Carbon.OSAconst — Carbon OSA Interface constants**

*Platforms:* Mac

### **36.8.44 Carbon.QDOffscreen — QuickDraw Offscreen constants**

*Platforms:* Mac

### **36.8.45 Carbon.Qd — QuickDraw**

*Platforms:* Mac

### **36.8.46 Carbon.Qdoffs — QuickDraw Offscreen**

*Platforms:* Mac

### **36.8.47 Carbon.Qt — QuickTime**

*Platforms:* Mac

### **36.8.48 Carbon.QuickDraw — QuickDraw constants**

*Platforms:* Mac

### **36.8.49 Carbon.QuickTime — QuickTime constants**

*Platforms:* Mac

### **36.8.50 Carbon.Res — Resource Manager and Handles**

*Platforms:* Mac

### **36.8.51 Carbon.Resources — Resource Manager and Handles constants**

*Platforms:* Mac

### 36.8.52 `Carbon.Scrap` — Scrap Manager

*Platforms:* Mac

This module is only fully available on Mac OS 9 and earlier under classic PPC MacPython. Very limited functionality is available under Carbon MacPython.

The Scrap Manager supports the simplest form of cut & paste operations on the Macintosh. It can be use for both inter- and intra-application clipboard operations.

The `Scrap` module provides low-level access to the functions of the Scrap Manager. It contains the following functions:

`Carbon.Scrap.InfoScrap()`

Return current information about the scrap. The information is encoded as a tuple containing the fields (`size`, `handle`, `count`, `state`, `path`).

Field	Meaning
<i>size</i>	Size of the scrap in bytes.
<i>handle</i>	Resource object representing the scrap.
<i>count</i>	Serial number of the scrap contents.
<i>state</i>	Integer; positive if in memory, 0 if on disk, negative if uninitialized.
<i>path</i>	Filename of the scrap when stored on disk.

**See Also:**

**Scrap Manager** Apple's documentation for the Scrap Manager gives a lot of useful information about using the Scrap Manager in applications.

### 36.8.53 `Carbon.Snd` — Sound Manager

*Platforms:* Mac

### 36.8.54 `Carbon.Sound` — Sound Manager constants

*Platforms:* Mac

### 36.8.55 `Carbon.TE` — TextEdit

*Platforms:* Mac

### 36.8.56 `Carbon.TextEdit` — TextEdit constants

*Platforms:* Mac

### 36.8.57 `Carbon.Win` — Window Manager

*Platforms:* Mac

### 36.8.58 `Carbon.Windows` — Window Manager constants

*Platforms:* Mac

## 36.9 ColorPicker — Color selection dialog

*Platforms:* Mac

The `ColorPicker` module provides access to the standard color picker dialog.

---

**Note:** This module has been removed in Python 3.x.

---

`ColorPicker.GetColor` (*prompt*, *rgb*)

Show a standard color selection dialog and allow the user to select a color. The user is given instruction by the *prompt* string, and the default color is set to *rgb*. *rgb* must be a tuple giving the red, green, and blue components of the color. `GetColor()` returns a tuple giving the user's selected color and a flag indicating whether they accepted the selection or cancelled.

# MACPYTHON OSA MODULES

This chapter describes the current implementation of the Open Scripting Architecture (OSA, also commonly referred to as AppleScript) for Python, allowing you to control scriptable applications from your Python program, and with a fairly pythonic interface. Development on this set of modules has stopped. For more up-to-date implementation of AppleScript support for Python, see the third-party py-appscript project: <<http://pypi.python.org/pypi/appscript/>>.

For a description of the various components of AppleScript and OSA, and to get an understanding of the architecture and terminology, you should read Apple’s documentation. The “Applescript Language Guide” explains the conceptual model and the terminology, and documents the standard suite. The “Open Scripting Architecture” document explains how to use OSA from an application programmers point of view. In the Apple Help Viewer these books are located in the Developer Documentation, Core Technologies section.

As an example of scripting an application, the following piece of AppleScript will get the name of the frontmost **Finder** window and print it:

```
tell application "Finder"
    get name of window 1
end tell
```

In Python, the following code fragment will do the same:

```
import Finder

f = Finder.Finder()
print f.get(f.window(1).name)
```

As distributed the Python library includes packages that implement the standard suites, plus packages that interface to a small number of common applications.

To send AppleEvents to an application you must first create the Python package interfacing to the terminology of the application (what **Script Editor** calls the “Dictionary”). This can be done from within the **PythonIDE** or by running the `gensuitemodule.py` module as a standalone program from the command line.

The generated output is a package with a number of modules, one for every suite used in the program plus an `__init__` module to glue it all together. The Python inheritance graph follows the AppleScript inheritance graph, so if a program’s dictionary specifies that it includes support for the Standard Suite, but extends one or two verbs with extra arguments then the output suite will contain a module `Standard_Suite` that imports and re-exports everything from `StdSuites.Standard_Suite` but overrides the methods that have extra functionality. The output of `gensuitemodule` is pretty readable, and contains the documentation that was in the original AppleScript dictionary in Python docstrings, so reading it is a good source of documentation.

The output package implements a main class with the same name as the package which contains all the AppleScript verbs as methods, with the direct object as the first argument and all optional parameters as keyword arguments. AppleScript classes are also implemented as Python classes, as are comparisons and all the other thingies.

The main Python class implementing the verbs also allows access to the properties and elements declared in the AppleScript class “application”. In the current release that is as far as the object orientation goes, so in the example above we need to use `f.get(f.window(1).name)` instead of the more Pythonic `f.window(1).name.get()`.

If an AppleScript identifier is not a Python identifier the name is mangled according to a small number of rules:

- spaces are replaced with underscores
- other non-alphanumeric characters are replaced with `__xx__` where `xx` is the hexadecimal character value
- any Python reserved word gets an underscore appended

Python also has support for creating scriptable applications in Python, but The following modules are relevant to MacPython AppleScript support:

## 37.1 gensuitemodule — Generate OSA stub packages

*Platforms:* Mac

The `gensuitemodule` module creates a Python package implementing stub code for the AppleScript suites that are implemented by a specific application, according to its AppleScript dictionary.

It is usually invoked by the user through the **PythonIDE**, but it can also be run as a script from the command line (pass `--help` for help on the options) or imported from Python code. For an example of its use see `Mac/scripts/genallsuites.py` in a source distribution, which generates the stub packages that are included in the standard library.

It defines the following public functions:

`gensuitemodule.is_scriptable(application)`

Returns true if `application`, which should be passed as a pathname, appears to be scriptable. Take the return value with a grain of salt: **Internet Explorer** appears not to be scriptable but definitely is.

`gensuitemodule.processfile(application[, output, basepkgname, edit_modnames, creatorsignature, dump, verbose])`

Create a stub package for `application`, which should be passed as a full pathname. For a `.app` bundle this is the pathname to the bundle, not to the executable inside the bundle; for an unbundled CFM application you pass the filename of the application binary.

This function asks the application for its OSA terminology resources, decodes these resources and uses the resultant data to create the Python code for the package implementing the client stubs.

`output` is the pathname where the resulting package is stored, if not specified a standard “save file as” dialog is presented to the user. `basepkgname` is the base package on which this package will build, and defaults to `StdSuites`. Only when generating `StdSuites` itself do you need to specify this. `edit_modnames` is a dictionary that can be used to change modulenames that are too ugly after name mangling. `creator_signature` can be used to override the 4-char creator code, which is normally obtained from the `PkgInfo` file in the package or from the CFM file creator signature. When `dump` is given it should refer to a file object, and `processfile` will stop after decoding the resources and dump the Python representation of the terminology resources to this file. `verbose` should also be a file object, and specifying it will cause `processfile` to tell you what it is doing.

`gensuitemodule.processfile_fromresource(application[, output, basepkgname, edit_modnames, creatorsignature, dump, verbose])`

This function does the same as `processfile`, except that it uses a different method to get the terminology resources. It opens `application` as a resource file and reads all “aete” and “aet” resources from this file.

## 37.2 aetools — OSA client support

*Platforms:* Mac

The `aetools` module contains the basic functionality on which Python AppleScript client support is built. It also imports and re-exports the core functionality of the `aetypes` and `aepack` modules. The stub packages generated by `gensuitemodule` import the relevant portions of `aetools`, so usually you do not need to import it yourself. The exception to this is when you cannot use a generated suite package and need lower-level access to scripting.

The `aetools` module itself uses the AppleEvent support provided by the `Carbon.AE` module. This has one drawback: you need access to the window manager, see section *osx-gui-scripts* for details. This restriction may be lifted in future releases.

---

**Note:** This module has been removed in Python 3.x.

---

The `aetools` module defines the following functions:

`aetools.packevent` (*ae, parameters, attributes*)

Stores parameters and attributes in a pre-created `Carbon.AE.AEDesc` object. `parameters` and `attributes` are dictionaries mapping 4-character OSA parameter keys to Python objects. The objects are packed using `aepack.pack()`.

`aetools.unpackevent` (*ae[, formodulename]*)

Recursively unpacks a `Carbon.AE.AEDesc` event to Python objects. The function returns the parameter dictionary and the attribute dictionary. The `formodulename` argument is used by generated stub packages to control where AppleScript classes are looked up.

`aetools.keysubst` (*arguments, keydict*)

Converts a Python keyword argument dictionary `arguments` to the format required by `packevent` by replacing the keys, which are Python identifiers, by the four-character OSA keys according to the mapping specified in `keydict`. Used by the generated suite packages.

`aetools.enumsbst` (*arguments, key, edict*)

If the `arguments` dictionary contains an entry for `key` convert the value for that entry according to dictionary `edict`. This converts human-readable Python enumeration names to the OSA 4-character codes. Used by the generated suite packages.

The `aetools` module defines the following class:

**class** `aetools.TalkTo` (*[signature=None, start=0, timeout=0]*)

Base class for the proxy used to talk to an application. `signature` overrides the class attribute `_signature` (which is usually set by subclasses) and is the 4-char creator code defining the application to talk to. `start` can be set to true to enable running the application on class instantiation. `timeout` can be specified to change the default timeout used while waiting for an AppleEvent reply.

`TalkTo._start` ()

Test whether the application is running, and attempt to start it if not.

`TalkTo.send` (*code, subcode[, parameters, attributes]*)

Create the AppleEvent `Carbon.AE.AEDesc` for the verb with the OSA designation `code`, `subcode` (which are the usual 4-character strings), pack the `parameters` and `attributes` into it, send it to the target application, wait for the reply, unpack the reply with `unpackevent` and return the reply appleevent, the unpacked return values as a dictionary and the return attributes.

## 37.3 `aepack` — Conversion between Python variables and AppleEvent data containers

Platforms: Mac

The `aepack` module defines functions for converting (packing) Python variables to AppleEvent descriptors and back (unpacking). Within Python the AppleEvent descriptor is handled by Python objects of built-in type `AEDesc`, defined in module `Carbon.AE`.

**Note:** This module has been removed in Python 3.x.

The `aepack` module defines the following functions:

`aepack.pack(x[, forcetype ])`

Returns an `AEDesc` object containing a conversion of Python value `x`. If `forcetype` is provided it specifies the descriptor type of the result. Otherwise, a default mapping of Python types to Apple Event descriptor types is used, as follows:

Python type	descriptor type
<code>FSSpec</code>	<code>typeFSS</code>
<code>FSRef</code>	<code>typeFSRef</code>
<code>Alias</code>	<code>typeAlias</code>
<code>integer</code>	<code>typeLong</code> (32 bit integer)
<code>float</code>	<code>typeFloat</code> (64 bit floating point)
<code>string</code>	<code>typeText</code>
<code>unicode</code>	<code>typeUnicodeText</code>
<code>list</code>	<code>typeAEList</code>
<code>dictionary</code>	<code>typeAERecord</code>
<code>instance</code>	<i>see below</i>

If `x` is a Python instance then this function attempts to call an `__aepack__()` method. This method should return an `AEDesc` object.

If the conversion `x` is not defined above, this function returns the Python string representation of a value (the `repr()` function) encoded as a text descriptor.

`aepack.unpack(x[, formodulename ])`

`x` must be an object of type `AEDesc`. This function returns a Python object representation of the data in the Apple Event descriptor `x`. Simple AppleEvent data types (integer, text, float) are returned as their obvious Python counterparts. Apple Event lists are returned as Python lists, and the list elements are recursively unpacked. Object references (ex. line 3 of document 1) are returned as instances of `aetypes.ObjectSpecifier`, unless `formodulename` is specified. AppleEvent descriptors with descriptor type `typeFSS` are returned as `FSSpec` objects. AppleEvent record descriptors are returned as Python dictionaries, with 4-character string keys and elements recursively unpacked.

The optional `formodulename` argument is used by the stub packages generated by `gensuitemodule`, and ensures that the OSA classes for object specifiers are looked up in the correct module. This ensures that if, say, the Finder returns an object specifier for a window you get an instance of `Finder.Window` and not a generic `aetypes.Window`. The former knows about all the properties and elements a window has in the Finder, while the latter knows no such things.

**See Also:**

**Module `Carbon.AE`** Built-in access to Apple Event Manager routines.

**Module `aetypes`** Python definitions of codes for Apple Event descriptor types.

## 37.4 aetypes — AppleEvent objects

*Platforms:* Mac

The `aetypes` defines classes used to represent Apple Event data descriptors and Apple Event object specifiers.

Apple Event data is contained in descriptors, and these descriptors are typed. For many descriptors the Python representation is simply the corresponding Python type: `typeText` in OSA is a Python string, `typeFloat` is a float, etc. For OSA types that have no direct Python counterpart this module declares classes. Packing and unpacking instances of these classes is handled automatically by `aepack`.

An object specifier is essentially an address of an object implemented in a Apple Event server. An Apple Event specifier is used as the direct object for an Apple Event or as the argument of an optional parameter. The `aetypes` module contains the base classes for OSA classes and properties, which are used by the packages generated by `gensuitemodule` to populate the classes and properties in a given suite.

For reasons of backward compatibility, and for cases where you need to script an application for which you have not generated the stub package this module also contains object specifiers for a number of common OSA classes such as `Document`, `Window`, `Character`, etc.

---

**Note:** This module has been removed in Python 3.x.

---

The `AEObjects` module defines the following classes to represent Apple Event descriptor data:

**class** `aetypes.Unknown` (*type, data*)

The representation of OSA descriptor data for which the `aepack` and `aetypes` modules have no support, i.e. anything that is not represented by the other classes here and that is not equivalent to a simple Python value.

**class** `aetypes.Enum` (*enum*)

An enumeration value with the given 4-character string value.

**class** `aetypes.InsertionLoc` (*of, pos*)

Position *pos* in object *of*.

**class** `aetypes.Boolean` (*bool*)

A boolean.

**class** `aetypes.StyledText` (*style, text*)

Text with style information (font, face, etc) included.

**class** `aetypes.AEText` (*script, style, text*)

Text with script system and style information included.

**class** `aetypes.IntlText` (*script, language, text*)

Text with script system and language information included.

**class** `aetypes.IntlWritingCode` (*script, language*)

Script system and language information.

**class** `aetypes.QDPoint` (*v, h*)

A quickdraw point.

**class** `aetypes.QDRectangle` (*v0, h0, v1, h1*)

A quickdraw rectangle.

**class** `aetypes.RGBColor` (*r, g, b*)

A color.

**class** `aetypes.Type` (*type*)

An OSA type value with the given 4-character name.

- class** `aetypes.Keyword` (*name*)  
An OSA keyword with the given 4-character name.
- class** `aetypes.Range` (*start, stop*)  
A range.
- class** `aetypes.Ordinal` (*abso*)  
Non-numeric absolute positions, such as "firs", first, or "midd", middle.
- class** `aetypes.Logical` (*logc, term*)  
The logical expression of applying operator `logc` to `term`.
- class** `aetypes.Comparison` (*obj1, relo, obj2*)  
The comparison `relo` of `obj1` to `obj2`.

The following classes are used as base classes by the generated stub packages to represent AppleScript classes and properties in Python:

- class** `aetypes.ComponentItem` (*which[, fr]*)  
Abstract baseclass for an OSA class. The subclass should set the class attribute `want` to the 4-character OSA class code. Instances of subclasses of this class are equivalent to AppleScript Object Specifiers. Upon instantiation you should pass a selector in `which`, and optionally a parent object in `fr`.
- class** `aetypes.NProperty` (*fr*)  
Abstract baseclass for an OSA property. The subclass should set the class attributes `want` and `which` to designate which property we are talking about. Instances of subclasses of this class are Object Specifiers.
- class** `aetypes.ObjectSpecifier` (*want, form, seld[, fr]*)  
Base class of `ComponentItem` and `NProperty`, a general OSA Object Specifier. See the Apple Open Scripting Architecture documentation for the parameters. Note that this class is not abstract.

## 37.5 MiniAEEFrame — Open Scripting Architecture server support

*Platforms:* Mac

The module `MiniAEEFrame` provides a framework for an application that can function as an Open Scripting Architecture (OSA) server, i.e. receive and process `AppleEvents`. It can be used in conjunction with `FrameWork` or standalone. As an example, it is used in `PythonCGISlave`.

The `MiniAEEFrame` module defines the following classes:

- class** `MiniAEEFrame.AEServer`  
A class that handles `AppleEvent` dispatch. Your application should subclass this class together with either `MiniApplication` or `FrameWork.Application`. Your `__init__()` method should call the `__init__()` method for both classes.
- class** `MiniAEEFrame.MinApplication`  
A class that is more or less compatible with `FrameWork.Application` but with less functionality. Its event loop supports the apple menu, command-dot and `AppleEvents`; other events are passed on to the Python interpreter and/or `Sioux`. Useful if your application wants to use `AEServer` but does not provide its own windows, etc.

### 37.5.1 AEServer Objects

- `AEServer.installaehandler` (*classe, type, callback*)  
Installs an `AppleEvent` handler. *classe* and *type* are the four-character OSA Class and Type designators, '\*\*\*\*'

wildcards are allowed. When a matching AppleEvent is received the parameters are decoded and your callback is invoked.

`AESEServer.callback(_object, **kwargs)`

Your callback is called with the OSA Direct Object as first positional parameter. The other parameters are passed as keyword arguments, with the 4-character designator as name. Three extra keyword parameters are passed: `_class` and `_type` are the Class and Type designators and `_attributes` is a dictionary with the AppleEvent attributes.

The return value of your method is packed with `aertools.packevent()` and sent as reply.

Note that there are some serious problems with the current design. AppleEvents which have non-identifier 4-character designators for arguments are not implementable, and it is not possible to return an error to the originator. This will be addressed in a future release.

In addition, support modules have been pre-generated for Finder, Terminal, Explorer, Netscape, CodeWarrior, SystemEvents and StdSuites.



# SGI IRIX SPECIFIC SERVICES

The modules described in this chapter provide interfaces to features that are unique to SGI's IRIX operating system (versions 4 and 5).

## 38.1 a1 — Audio functions on the SGI

*Platforms:* IRIX

Deprecated since version 2.6: The `a1` module has been removed in Python 3. This module provides access to the audio facilities of the SGI Indy and Indigo workstations. See section 3A of the IRIX man pages for details. You'll need to read those man pages to understand what these functions do! Some of the functions are not available in IRIX releases before 4.0.5. Again, see the manual to check whether a specific function is available on your platform.

All functions and methods defined in this module are equivalent to the C functions with `AL` prefixed to their name.

Symbolic constants from the C header file `<audio.h>` are defined in the standard module `AL`, see below.

**Warning:** The current version of the audio library may dump core when bad argument values are passed rather than returning an error status. Unfortunately, since the precise circumstances under which this may happen are undocumented and hard to check, the Python interface can provide no protection against this kind of problems. (One example is specifying an excessive queue size — there is no documented upper limit.)

The module defines the following functions:

`a1.openport` (*name*, *direction*[, *config* ])

The *name* and *direction* arguments are strings. The optional *config* argument is a configuration object as returned by `newconfig()`. The return value is an *audio port object*; methods of audio port objects are described below.

`a1.newconfig` ()

The return value is a new *audio configuration object*; methods of audio configuration objects are described below.

`a1.queryparams` (*device*)

The *device* argument is an integer. The return value is a list of integers containing the data returned by `ALqueryparams()`.

`a1.getparams` (*device*, *list*)

The *device* argument is an integer. The *list* argument is a list such as returned by `queryparams()`; it is modified in place (!).

`a1.setparams` (*device*, *list*)

The *device* argument is an integer. The *list* argument is a list such as returned by `queryparams()`.

### 38.1.1 Configuration Objects

Configuration objects returned by `newconfig()` have the following methods:

- `audio configuration.getqueuesize()`**  
Return the queue size.
- `audio configuration.setqueuesize(size)`**  
Set the queue size.
- `audio configuration.getwidth()`**  
Get the sample width.
- `audio configuration.setwidth(width)`**  
Set the sample width.
- `audio configuration.getchannels()`**  
Get the channel count.
- `audio configuration.setchannels(nchannels)`**  
Set the channel count.
- `audio configuration.getsampfmt()`**  
Get the sample format.
- `audio configuration.setsampfmt(sampfmt)`**  
Set the sample format.
- `audio configuration.getfloatmax()`**  
Get the maximum value for floating sample formats.
- `audio configuration.setfloatmax(floatmax)`**  
Set the maximum value for floating sample formats.

### 38.1.2 Port Objects

Port objects, as returned by `openport()`, have the following methods:

- `audio port.closeport()`**  
Close the port.
- `audio port.getfd()`**  
Return the file descriptor as an int.
- `audio port.getfilled()`**  
Return the number of filled samples.
- `audio port.getfillable()`**  
Return the number of fillable samples.
- `audio port.readsamps(nsamples)`**  
Read a number of samples from the queue, blocking if necessary. Return the data as a string containing the raw data, (e.g., 2 bytes per sample in big-endian byte order (high byte, low byte) if you have set the sample width to 2 bytes).
- `audio port.writesamps(samples)`**  
Write samples into the queue, blocking if necessary. The samples are encoded as described for the `readsamps()` return value.
- `audio port.getfillpoint()`**  
Return the 'fill point'.

**audio port.setfillpoint(fillpoint)**

Set the 'fill point'.

**audio port.getconfig()**

Return a configuration object containing the current configuration of the port.

**audio port.setconfig(config)**

Set the configuration from the argument, a configuration object.

**audio port.getstatus(list)**

Get status information on last error.

## 38.2 AL — Constants used with the a1 module

*Platforms:* IRIX

Deprecated since version 2.6: The `AL` module has been removed in Python 3. This module defines symbolic constants needed to use the built-in module `a1` (see above); they are equivalent to those defined in the C header file `<audio.h>` except that the name prefix `AL_` is omitted. Read the module source for a complete list of the defined names. Suggested use:

```
import a1
from AL import *
```

## 38.3 cd — CD-ROM access on SGI systems

*Platforms:* IRIX

Deprecated since version 2.6: The `cd` module has been removed in Python 3. This module provides an interface to the Silicon Graphics CD library. It is available only on Silicon Graphics systems.

The way the library works is as follows. A program opens the CD-ROM device with `open()` and creates a parser to parse the data from the CD with `createparser()`. The object returned by `open()` can be used to read data from the CD, but also to get status information for the CD-ROM device, and to get information about the CD, such as the table of contents. Data from the CD is passed to the parser, which parses the frames, and calls any callback functions that have previously been added.

An audio CD is divided into *tracks* or *programs* (the terms are used interchangeably). Tracks can be subdivided into *indices*. An audio CD contains a *table of contents* which gives the starts of the tracks on the CD. Index 0 is usually the pause before the start of a track. The start of the track as given by the table of contents is normally the start of index 1.

Positions on a CD can be represented in two ways. Either a frame number or a tuple of three values, minutes, seconds and frames. Most functions use the latter representation. Positions can be both relative to the beginning of the CD, and to the beginning of the track.

Module `cd` defines the following functions and constants:

`cd.createparser()`

Create and return an opaque parser object. The methods of the parser object are described below.

`cd.msftoframe(minutes, seconds, frames)`

Converts a (minutes, seconds, frames) triple representing time in absolute time code into the corresponding CD frame number.

`cd.open([device[, mode]])`

Open the CD-ROM device. The return value is an opaque player object; methods of the player object are described below. The device is the name of the SCSI device file, e.g. `'/dev/scsi/sc0d410'`, or `None`.

If omitted or `None`, the hardware inventory is consulted to locate a CD-ROM drive. The *mode*, if not omitted, should be the string `'r'`.

The module defines the following variables:

**exception `cd.error`**

Exception raised on various errors.

**`cd.DATASIZE`**

The size of one frame's worth of audio data. This is the size of the audio data as passed to the callback of type `audio`.

**`cd.BLOCKSIZE`**

The size of one uninterpreted frame of audio data.

The following variables are states as returned by `getstatus()`:

**`cd.READY`**

The drive is ready for operation loaded with an audio CD.

**`cd.NODISC`**

The drive does not have a CD loaded.

**`cd.CDROM`**

The drive is loaded with a CD-ROM. Subsequent play or read operations will return I/O errors.

**`cd.ERROR`**

An error occurred while trying to read the disc or its table of contents.

**`cd.PLAYING`**

The drive is in CD player mode playing an audio CD through its audio jacks.

**`cd.PAUSED`**

The drive is in CD layer mode with play paused.

**`cd.STILL`**

The equivalent of `PAUSED` on older (non 3301) model Toshiba CD-ROM drives. Such drives have never been shipped by SGI.

**`cd.audio`**

**`cd.pnum`**

**`cd.index`**

**`cd.ptime`**

**`cd.atime`**

**`cd.catalog`**

**`cd.ident`**

**`cd.control`**

Integer constants describing the various types of parser callbacks that can be set by the `addcallback()` method of CD parser objects (see below).

### 38.3.1 Player Objects

Player objects (returned by `open()`) have the following methods:

**CD `player.allowremoval()`**

Unlocks the eject button on the CD-ROM drive permitting the user to eject the caddy if desired.

**CD `player.bestreadsize()`**

Returns the best value to use for the `num_frames` parameter of the `readdata()` method. Best is defined as the value that permits a continuous flow of data from the CD-ROM drive.

- CD `player.close()`**  
 Frees the resources associated with the player object. After calling `close()`, the methods of the object should no longer be used.
- CD `player.eject()`**  
 Ejects the caddy from the CD-ROM drive.
- CD `player.getstatus()`**  
 Returns information pertaining to the current state of the CD-ROM drive. The returned information is a tuple with the following values: *state*, *track*, *rtime*, *atime*, *ttime*, *first*, *last*, *scsi\_audio*, *cur\_block*. *rtime* is the time relative to the start of the current track; *atime* is the time relative to the beginning of the disc; *ttime* is the total time on the disc. For more information on the meaning of the values, see the man page `CDgetstatus(3dm)`. The value of *state* is one of the following: `ERROR`, `NODISC`, `READY`, `PLAYING`, `PAUSED`, `STILL`, or `CDROM`.
- CD `player.gettrackinfo(track)`**  
 Returns information about the specified track. The returned information is a tuple consisting of two elements, the start time of the track and the duration of the track.
- CD `player.msftoblock(min, sec, frame)`**  
 Converts a minutes, seconds, frames triple representing a time in absolute time code into the corresponding logical block number for the given CD-ROM drive. You should use `msftoframe()` rather than `msftoblock()` for comparing times. The logical block number differs from the frame number by an offset required by certain CD-ROM drives.
- CD `player.play(start, play)`**  
 Starts playback of an audio CD in the CD-ROM drive at the specified track. The audio output appears on the CD-ROM drive's headphone and audio jacks (if fitted). Play stops at the end of the disc. *start* is the number of the track at which to start playing the CD; if *play* is 0, the CD will be set to an initial paused state. The method `togglepause()` can then be used to commence play.
- CD `player.playabs(minutes, seconds, frames, play)`**  
 Like `play()`, except that the start is given in minutes, seconds, and frames instead of a track number.
- CD `player.playtrack(start, play)`**  
 Like `play()`, except that playing stops at the end of the track.
- CD `player.playtrackabs(track, minutes, seconds, frames, play)`**  
 Like `play()`, except that playing begins at the specified absolute time and ends at the end of the specified track.
- CD `player.preventremoval()`**  
 Locks the eject button on the CD-ROM drive thus preventing the user from arbitrarily ejecting the caddy.
- CD `player.reada(num_frames)`**  
 Reads the specified number of frames from an audio CD mounted in the CD-ROM drive. The return value is a string representing the audio frames. This string can be passed unaltered to the `parseframe()` method of the parser object.
- CD `player.seek(minutes, seconds, frames)`**  
 Sets the pointer that indicates the starting point of the next read of digital audio data from a CD-ROM. The pointer is set to an absolute time code location specified in *minutes*, *seconds*, and *frames*. The return value is the logical block number to which the pointer has been set.
- CD `player.seekblock(block)`**  
 Sets the pointer that indicates the starting point of the next read of digital audio data from a CD-ROM. The pointer is set to the specified logical block number. The return value is the logical block number to which the pointer has been set.
- CD `player.seektrack(track)`**  
 Sets the pointer that indicates the starting point of the next read of digital audio data from a CD-ROM. The

pointer is set to the specified track. The return value is the logical block number to which the pointer has been set.

**CD `player.stop()`**

Stops the current playing operation.

**CD `player.togglepause()`**

Pauses the CD if it is playing, and makes it play if it is paused.

### 38.3.2 Parser Objects

Parser objects (returned by `createparser()`) have the following methods:

**CD `parser.addcallback(type, func, arg)`**

Adds a callback for the parser. The parser has callbacks for eight different types of data in the digital audio data stream. Constants for these types are defined at the `cd` module level (see above). The callback is called as follows: `func(arg, type, data)`, where *arg* is the user supplied argument, *type* is the particular type of callback, and *data* is the data returned for this *type* of callback. The type of the data depends on the *type* of callback as follows:

Type	Value
<code>audio</code>	String which can be passed unmodified to <code>al.writesamps()</code> .
<code>pnum</code>	Integer giving the program (track) number.
<code>index</code>	Integer giving the index number.
<code>ptime</code>	Tuple consisting of the program time in minutes, seconds, and frames.
<code>atime</code>	Tuple consisting of the absolute time in minutes, seconds, and frames.
<code>catalog</code>	String of 13 characters, giving the catalog number of the CD.
<code>ident</code>	String of 12 characters, giving the ISRC identification number of the recording. The string consists of two characters country code, three characters owner code, two characters giving the year, and five characters giving a serial number.
<code>control</code>	Integer giving the control bits from the CD subcode data

**CD `parser.deleteparser()`**

Deletes the parser and frees the memory it was using. The object should not be used after this call. This call is done automatically when the last reference to the object is removed.

**CD `parser.parseframe(frame)`**

Parses one or more frames of digital audio data from a CD such as returned by `readda()`. It determines which subcodes are present in the data. If these subcodes have changed since the last frame, then `parseframe()` executes a callback of the appropriate type passing to it the subcode data found in the frame. Unlike the `C` function, more than one frame of digital audio data can be passed to this method.

**CD `parser.removecallback(type)`**

Removes the callback for the given *type*.

**CD `parser.resetparser()`**

Resets the fields of the parser used for tracking subcodes to an initial state. `resetparser()` should be called after the disc has been changed.

## 38.4 `fl` — FORMS library for graphical user interfaces

*Platforms:* IRIX

Deprecated since version 2.6: The `fl` module has been removed in Python 3. This module provides an interface to the FORMS Library by Mark Overmars. The source for the library can be retrieved by anonymous ftp from host `ftp.cs.ruu.nl`, directory `SGI/FORMS`. It was last tested with version 2.0b.

Most functions are literal translations of their C equivalents, dropping the initial `fl_` from their name. Constants used by the library are defined in module `FL` described below.

The creation of objects is a little different in Python than in C: instead of the ‘current form’ maintained by the library to which new FORMS objects are added, all functions that add a FORMS object to a form are methods of the Python object representing the form. Consequently, there are no Python equivalents for the C functions `fl_addto_form()` and `fl_end_form()`, and the equivalent of `fl_bgn_form()` is called `fl.make_form()`.

Watch out for the somewhat confusing terminology: FORMS uses the word *object* for the buttons, sliders etc. that you can place in a form. In Python, ‘object’ means any value. The Python interface to FORMS introduces two new Python object types: form objects (representing an entire form) and FORMS objects (representing one button, slider etc.). Hopefully this isn’t too confusing.

There are no ‘free objects’ in the Python interface to FORMS, nor is there an easy way to add object classes written in Python. The FORMS interface to GL event handling is available, though, so you can mix FORMS with pure GL windows.

**Please note:** importing `fl` implies a call to the GL function `foreground()` and to the FORMS routine `fl_init()`.

### 38.4.1 Functions Defined in Module `fl`

Module `fl` defines the following functions. For more information about what they do, see the description of the equivalent C function in the FORMS documentation:

`fl.make_form` (*type, width, height*)

Create a form with given type, width and height. This returns a *form* object, whose methods are described below.

`fl.do_forms` ()

The standard FORMS main loop. Returns a Python object representing the FORMS object needing interaction, or the special value `FL.EVENT`.

`fl.check_forms` ()

Check for FORMS events. Returns what `do_forms()` above returns, or `None` if there is no event that immediately needs interaction.

`fl.set_event_callback` (*function*)

Set the event callback function.

`fl.set_graphics_mode` (*rgbmode, doublebuffering*)

Set the graphics modes.

`fl.get_rgbmode` ()

Return the current rgb mode. This is the value of the C global variable `fl_rgbmode`.

`fl.show_message` (*str1, str2, str3*)

Show a dialog box with a three-line message and an OK button.

`fl.show_question` (*str1, str2, str3*)

Show a dialog box with a three-line message and YES and NO buttons. It returns 1 if the user pressed YES, 0 if NO.

`fl.show_choice` (*str1, str2, str3, but1[, but2[, but3]]*)

Show a dialog box with a three-line message and up to three buttons. It returns the number of the button clicked by the user (1, 2 or 3).

`fl.show_input` (*prompt, default*)

Show a dialog box with a one-line prompt message and text field in which the user can enter a string. The second argument is the default input string. It returns the string value as edited by the user.

`fl.show_file_selector` (*message, directory, pattern, default*)

Show a dialog box in which the user can select a file. It returns the absolute filename selected by the user, or None if the user presses Cancel.

`fl.get_directory` ()

`fl.get_pattern` ()

`fl.get_filename` ()

These functions return the directory, pattern and filename (the tail part only) selected by the user in the last `show_file_selector` () call.

`fl.qdevice` (*dev*)

`fl.unqdevice` (*dev*)

`fl.isqueued` (*dev*)

`fl.qtest` ()

`fl.qread` ()

`fl.qreset` ()

`fl.qenter` (*dev, val*)

`fl.get_mouse` ()

`fl.tie` (*button, valuator1, valuator2*)

These functions are the FORMS interfaces to the corresponding GL functions. Use these if you want to handle some GL events yourself when using `fl.do_events` (). When a GL event is detected that FORMS cannot handle, `fl.do_forms` () returns the special value `FL.EVENT` and you should call `fl.qread` () to read the event from the queue. Don't use the equivalent GL functions!

`fl.color` ()

`fl.mapcolor` ()

`fl.getmcolor` ()

See the description in the FORMS documentation of `fl_color` (), `fl_mapcolor` () and `fl_getmcolor` () .

## 38.4.2 Form Objects

Form objects (returned by `make_form` () above) have the following methods. Each method corresponds to a C function whose name is prefixed with `fl_`; and whose first argument is a form pointer; please refer to the official FORMS documentation for descriptions.

All the `add_*` () methods return a Python object representing the FORMS object. Methods of FORMS objects are described below. Most kinds of FORMS object also have some methods specific to that kind; these methods are listed here.

`form.show_form` (*placement, bordertype, name*)

Show the form.

`form.hide_form` ()

Hide the form.

`form.redraw_form` ()

Redraw the form.

`form.set_form_position` (*x, y*)

Set the form's position.

`form.freeze_form` ()

Freeze the form.

`form.unfreeze_form` ()

Unfreeze the form.

- `form.activate_form()`  
Activate the form.
- `form.deactivate_form()`  
Deactivate the form.
- `form.bgn_group()`  
Begin a new group of objects; return a group object.
- `form.end_group()`  
End the current group of objects.
- `form.find_first()`  
Find the first object in the form.
- `form.find_last()`  
Find the last object in the form.
- `form.add_box(type, x, y, w, h, name)`  
Add a box object to the form. No extra methods.
- `form.add_text(type, x, y, w, h, name)`  
Add a text object to the form. No extra methods.
- `form.add_clock(type, x, y, w, h, name)`  
Add a clock object to the form. — Method: `get_clock()`.
- `form.add_button(type, x, y, w, h, name)`  
Add a button object to the form. — Methods: `get_button()`, `set_button()`.
- `form.add_lightbutton(type, x, y, w, h, name)`  
Add a lightbutton object to the form. — Methods: `get_button()`, `set_button()`.
- `form.add_roundbutton(type, x, y, w, h, name)`  
Add a roundbutton object to the form. — Methods: `get_button()`, `set_button()`.
- `form.add_slider(type, x, y, w, h, name)`  
Add a slider object to the form. — Methods: `set_slider_value()`, `get_slider_value()`, `set_slider_bounds()`, `get_slider_bounds()`, `set_slider_return()`, `set_slider_size()`, `set_slider_precision()`, `set_slider_step()`.
- `form.add_valslider(type, x, y, w, h, name)`  
Add a valslider object to the form. — Methods: `set_slider_value()`, `get_slider_value()`, `set_slider_bounds()`, `get_slider_bounds()`, `set_slider_return()`, `set_slider_size()`, `set_slider_precision()`, `set_slider_step()`.
- `form.add_dial(type, x, y, w, h, name)`  
Add a dial object to the form. — Methods: `set_dial_value()`, `get_dial_value()`, `set_dial_bounds()`, `get_dial_bounds()`.
- `form.add_positioner(type, x, y, w, h, name)`  
Add a positioner object to the form. — Methods: `set_positioner_xvalue()`, `set_positioner_yvalue()`, `set_positioner_xbounds()`, `set_positioner_ybounds()`, `get_positioner_xvalue()`, `get_positioner_yvalue()`, `get_positioner_xbounds()`, `get_positioner_ybounds()`.
- `form.add_counter(type, x, y, w, h, name)`  
Add a counter object to the form. — Methods: `set_counter_value()`, `get_counter_value()`, `set_counter_bounds()`, `set_counter_step()`, `set_counter_precision()`, `set_counter_return()`.

`form.add_input (type, x, y, w, h, name)`

Add a input object to the form. — Methods: `set_input ()`, `get_input ()`, `set_input_color ()`, `set_input_return ()`.

`form.add_menu (type, x, y, w, h, name)`

Add a menu object to the form. — Methods: `set_menu ()`, `get_menu ()`, `addto_menu ()`.

`form.add_choice (type, x, y, w, h, name)`

Add a choice object to the form. — Methods: `set_choice ()`, `get_choice ()`, `clear_choice ()`, `addto_choice ()`, `replace_choice ()`, `delete_choice ()`, `get_choice_text ()`, `set_choice_fontsize ()`, `set_choice_fontstyle ()`.

`form.add_browser (type, x, y, w, h, name)`

Add a browser object to the form. — Methods: `set_browser_topline ()`, `clear_browser ()`, `add_browser_line ()`, `addto_browser ()`, `insert_browser_line ()`, `delete_browser_line ()`, `replace_browser_line ()`, `get_browser_line ()`, `load_browser ()`, `get_browser_maxline ()`, `select_browser_line ()`, `deselect_browser_line ()`, `deselect_browser ()`, `isselected_browser_line ()`, `get_browser ()`, `set_browser_fontsize ()`, `set_browser_fontstyle ()`, `set_browser_specialkey ()`.

`form.add_timer (type, x, y, w, h, name)`

Add a timer object to the form. — Methods: `set_timer ()`, `get_timer ()`.

Form objects have the following data attributes; see the FORMS documentation:

Name	C Type	Meaning
<code>window</code>	int (read-only)	GL window id
<code>w</code>	float	form width
<code>h</code>	float	form height
<code>x</code>	float	form x origin
<code>y</code>	float	form y origin
<code>deactivated</code>	int	nonzero if form is deactivated
<code>visible</code>	int	nonzero if form is visible
<code>frozen</code>	int	nonzero if form is frozen
<code>doublebuf</code>	int	nonzero if double buffering on

### 38.4.3 FORMS Objects

Besides methods specific to particular kinds of FORMS objects, all FORMS objects also have the following methods:

**FORMS object.set\_callback (function, argument)**

Set the object's callback function and argument. When the object needs interaction, the callback function will be called with two arguments: the object, and the callback argument. (FORMS objects without a callback function are returned by `fl.do_forms ()` or `fl.check_forms ()` when they need interaction.) Call this method without arguments to remove the callback function.

**FORMS object.delete\_object ()**

Delete the object.

**FORMS object.show\_object ()**

Show the object.

**FORMS object.hide\_object ()**

Hide the object.

**FORMS object.redraw\_object ()**

Redraw the object.

**FORMS** `object.freeze_object()`

Freeze the object.

**FORMS** `object.unfreeze_object()`

Unfreeze the object.

FORMS objects have these data attributes; see the FORMS documentation:

Name	C Type	Meaning
<code>objclass</code>	int (read-only)	object class
<code>type</code>	int (read-only)	object type
<code>boxtype</code>	int	box type
<code>x</code>	float	x origin
<code>y</code>	float	y origin
<code>w</code>	float	width
<code>h</code>	float	height
<code>col1</code>	int	primary color
<code>col2</code>	int	secondary color
<code>align</code>	int	alignment
<code>lcol</code>	int	label color
<code>lsize</code>	float	label font size
<code>label</code>	string	label string
<code>lstyle</code>	int	label style
<code>pushed</code>	int (read-only)	(see FORMS docs)
<code>focus</code>	int (read-only)	(see FORMS docs)
<code>belowmouse</code>	int (read-only)	(see FORMS docs)
<code>frozen</code>	int (read-only)	(see FORMS docs)
<code>active</code>	int (read-only)	(see FORMS docs)
<code>input</code>	int (read-only)	(see FORMS docs)
<code>visible</code>	int (read-only)	(see FORMS docs)
<code>radio</code>	int (read-only)	(see FORMS docs)
<code>automatic</code>	int (read-only)	(see FORMS docs)

## 38.5 FL — Constants used with the fl module

*Platforms:* IRIX

Deprecated since version 2.6: The `FL` module has been removed in Python 3. This module defines symbolic constants needed to use the built-in module `fl` (see above); they are equivalent to those defined in the C header file `<forms.h>` except that the name prefix `FL_` is omitted. Read the module source for a complete list of the defined names. Suggested use:

```
import fl
from FL import *
```

## 38.6 flp — Functions for loading stored FORMS designs

*Platforms:* IRIX

Deprecated since version 2.6: The `flp` module has been removed in Python 3. This module defines functions that can read form definitions created by the ‘form designer’ (`fdesign`) program that comes with the FORMS library (see module `fl` above).

For now, see the file `flp.doc` in the Python library source directory for a description.

XXX A complete description should be inserted here!

## 38.7 `fm` — *Font Manager* interface

*Platforms:* IRIX

Deprecated since version 2.6: The `fm` module has been removed in Python 3. This module provides access to the IRIS *Font Manager* library. It is available only on Silicon Graphics machines. See also: *4Sight User's Guide*, section 1, chapter 5: "Using the IRIS Font Manager."

This is not yet a full interface to the IRIS Font Manager. Among the unsupported features are: matrix operations; cache operations; character operations (use string operations instead); some details of font info; individual glyph metrics; and printer matching.

It supports the following operations:

`fm.init()`

Initialization function. Calls `fm_init()`. It is normally not necessary to call this function, since it is called automatically the first time the `fm` module is imported.

`fm.findfont(fontname)`

Return a font handle object. Calls `fmfindfont(fontname)`.

`fm.enumerate()`

Returns a list of available font names. This is an interface to `fmenumerate()`.

`fm.prstr(string)`

Render a string using the current font (see the `setfont()` font handle method below). Calls `fmprstr(string)`.

`fm.setpath(string)`

Sets the font search path. Calls `fmsetpath(string)`. (XXX Does not work!?)

`fm.fontpath()`

Returns the current font search path.

Font handle objects support the following operations:

**font handle.scalefont(factor)**

Returns a handle for a scaled version of this font. Calls `fmscalefont(fh, factor)`.

**font handle.setfont()**

Makes this font the current font. Note: the effect is undone silently when the font handle object is deleted. Calls `fmsetfont(fh)`.

**font handle.getfontname()**

Returns this font's name. Calls `fmgetfontname(fh)`.

**font handle.getcomment()**

Returns the comment string associated with this font. Raises an exception if there is none. Calls `fmgetcomment(fh)`.

**font handle.getfontinfo()**

Returns a tuple giving some pertinent data about this font. This is an interface to `fmgetfontinfo()`. The returned tuple contains the following numbers: (`printermatched`, `fixed_width`, `xorig`, `yorig`, `xsize`, `ysize`, `height`, `nglyphs`).

**font handle.getstrwidth(string)**

Returns the width, in pixels, of *string* when drawn in this font. Calls `fmgetstrwidth(fh, string)`.

## 38.8 gl — Graphics Library interface

Platforms: IRIX

Deprecated since version 2.6: The `gl` module has been removed in Python 3. This module provides access to the Silicon Graphics *Graphics Library*. It is available only on Silicon Graphics machines.

**Warning:** Some illegal calls to the GL library cause the Python interpreter to dump core. In particular, the use of most GL calls is unsafe before the first window is opened.

The module is too large to document here in its entirety, but the following should help you to get started. The parameter conventions for the C functions are translated to Python as follows:

- All (short, long, unsigned) int values are represented by Python integers.
- All float and double values are represented by Python floating point numbers. In most cases, Python integers are also allowed.
- All arrays are represented by one-dimensional Python lists. In most cases, tuples are also allowed.
- All string and character arguments are represented by Python strings, for instance, `winopen('Hi There!')` and `rotate(900, 'z')`.
- All (short, long, unsigned) integer arguments or return values that are only used to specify the length of an array argument are omitted. For example, the C call

```
lmdef(deftype, index, np, props)
```

is translated to Python as

```
lmdef(deftype, index, props)
```

- Output arguments are omitted from the argument list; they are transmitted as function return values instead. If more than one value must be returned, the return value is a tuple. If the C function has both a regular return value (that is not omitted because of the previous rule) and an output argument, the return value comes first in the tuple. Examples: the C call

```
getmcolor(i, &red, &green, &blue)
```

is translated to Python as

```
red, green, blue = getmcolor(i)
```

The following functions are non-standard or have special argument conventions:

`gl.varray` (*argument*)

Equivalent to but faster than a number of `v3d()` calls. The *argument* is a list (or tuple) of points. Each point must be a tuple of coordinates  $(x, y, z)$  or  $(x, y)$ . The points may be 2- or 3-dimensional but must all have the same dimension. Float and int values may be mixed however. The points are always converted to 3D double precision points by assuming  $z = 0.0$  if necessary (as indicated in the man page), and for each point `v3d()` is called.

`gl.nvarray` ()

Equivalent to but faster than a number of `n3f` and `v3f` calls. The argument is an array (list or tuple) of pairs of normals and points. Each pair is a tuple of a point and a normal for that point. Each point or normal must be a tuple of coordinates  $(x, y, z)$ . Three coordinates must be given. Float and int values may be mixed. For each pair, `n3f()` is called for the normal, and then `v3f()` is called for the point.

`gl.vnarray` ()

Similar to `nvarray()` but the pairs have the point first and the normal second.

`gl.nurbsurface` (*s\_k, t\_k, ctl, s\_ord, t\_ord, type*)

Defines a nurbs surface. The dimensions of `ctl` are computed as follows: `[len(s_k) - s_ord], [len(t_k) - t_ord]`.

`gl.nurbscurve` (*knots, ctlpoints, order, type*)

Defines a nurbs curve. The length of `ctlpoints` is `len(knots) - order`.

`gl.pwlcurve` (*points, type*)

Defines a piecewise-linear curve. *points* is a list of points. *type* must be `N_ST`.

`gl.pick` (*n*)

`gl.select` (*n*)

The only argument to these functions specifies the desired size of the pick or select buffer.

`gl.endpick` ()

`gl.endselect` ()

These functions have no arguments. They return a list of integers representing the used part of the pick/select buffer. No method is provided to detect buffer overrun.

Here is a tiny but complete example GL program in Python:

```
import gl, GL, time
```

```
def main():
    gl.foreground()
    gl.prefposition(500, 900, 500, 900)
    w = gl.winopen('CrissCross')
    gl.ortho2(0.0, 400.0, 0.0, 400.0)
    gl.color(GL.WHITE)
    gl.clear()
    gl.color(GL.RED)
    gl.bgnline()
    gl.v2f(0.0, 0.0)
    gl.v2f(400.0, 400.0)
    gl.endline()
    gl.bgnline()
    gl.v2f(400.0, 0.0)
    gl.v2f(0.0, 400.0)
    gl.endline()
    time.sleep(5)
```

```
main()
```

**See Also:**

**PyOpenGL: The Python OpenGL Binding** An interface to OpenGL is also available; see information about the **PyOpenGL** project online at <http://pyopengl.sourceforge.net/>. This may be a better option if support for SGI hardware from before about 1996 is not required.

## 38.9 DEVICE — Constants used with the `gl` module

*Platforms:* IRIX

Deprecated since version 2.6: The `DEVICE` module has been removed in Python 3. This module defines the constants used by the Silicon Graphics *Graphics Library* that C programmers find in the header file `<gl/device.h>`. Read the module source file for details.

## 38.10 GL — Constants used with the `gl` module

*Platforms:* IRIX

Deprecated since version 2.6: The `GL` module has been removed in Python 3. This module contains constants used by the Silicon Graphics *Graphics Library* from the C header file `<gl/gl.h>`. Read the module source file for details.

## 38.11 `imgfile` — Support for SGI `imglib` files

*Platforms:* IRIX

Deprecated since version 2.6: The `imgfile` module has been removed in Python 3. The `imgfile` module allows Python programs to access SGI `imglib` image files (also known as `.rgb` files). The module is far from complete, but is provided anyway since the functionality that there is enough in some cases. Currently, colormap files are not supported.

The module defines the following variables and functions:

### exception `imgfile.error`

This exception is raised on all errors, such as unsupported file type, etc.

### `imgfile.getsizes` (*file*)

This function returns a tuple  $(x, y, z)$  where  $x$  and  $y$  are the size of the image in pixels and  $z$  is the number of bytes per pixel. Only 3 byte RGB pixels and 1 byte greyscale pixels are currently supported.

### `imgfile.read` (*file*)

This function reads and decodes the image on the specified file, and returns it as a Python string. The string has either 1 byte greyscale pixels or 4 byte RGBA pixels. The bottom left pixel is the first in the string. This format is suitable to pass to `gl.lrectwrite()`, for instance.

### `imgfile.readscaled` (*file*, $x$ , $y$ , *filter* [, *blur* ])

This function is identical to `read` but it returns an image that is scaled to the given  $x$  and  $y$  sizes. If the *filter* and *blur* parameters are omitted scaling is done by simply dropping or duplicating pixels, so the result will be less than perfect, especially for computer-generated images.

Alternatively, you can specify a filter to use to smooth the image after scaling. The filter forms supported are 'impulse', 'box', 'triangle', 'quadratic' and 'gaussian'. If a filter is specified *blur* is an optional parameter specifying the blurriness of the filter. It defaults to 1.0.

`readscaled()` makes no attempt to keep the aspect ratio correct, so that is the users' responsibility.

### `imgfile.ttob` (*flag*)

This function sets a global flag which defines whether the scan lines of the image are read or written from bottom to top (*flag* is zero, compatible with SGI GL) or from top to bottom (*flag* is one, compatible with X). The default is zero.

### `imgfile.write` (*file*, *data*, $x$ , $y$ , $z$ )

This function writes the RGB or greyscale data in *data* to image file *file*.  $x$  and  $y$  give the size of the image,  $z$  is 1 for 1 byte greyscale images or 3 for RGB images (which are stored as 4 byte values of which only the lower three bytes are used). These are the formats returned by `gl.lrectread()`.

## 38.12 `jpeg` — Read and write JPEG files

*Platforms:* IRIX

Deprecated since version 2.6: The `jpeg` module has been removed in Python 3. The module `jpeg` provides access to the jpeg compressor and decompressor written by the Independent JPEG Group (IJG). JPEG is a standard for compressing pictures; it is defined in ISO 10918. For details on JPEG or the Independent JPEG Group software refer to the JPEG standard or the documentation provided with the software.

A portable interface to JPEG image files is available with the Python Imaging Library (PIL) by Fredrik Lundh. Information on PIL is available at <http://www.pythonware.com/products/pil/>.

The `jpeg` module defines an exception and some functions.

### exception `jpeg.error`

Exception raised by `compress()` and `decompress()` in case of errors.

### `jpeg.compress(data, w, h, b)`

Treat data as a pixmap of width `w` and height `h`, with `b` bytes per pixel. The data is in SGI GL order, so the first pixel is in the lower-left corner. This means that `gl.rectread()` return data can immediately be passed to `compress()`. Currently only 1 byte and 4 byte pixels are allowed, the former being treated as greyscale and the latter as RGB color. `compress()` returns a string that contains the compressed picture, in JFIF format.

### `jpeg.decompress(data)`

Data is a string containing a picture in JFIF format. It returns a tuple (`data`, `width`, `height`, `bytesperpixel`). Again, the data is suitable to pass to `gl.rectwrite()`.

### `jpeg.setoption(name, value)`

Set various options. Subsequent `compress()` and `decompress()` calls will use these options. The following options are available:

Option	Effect
'forcegray'	Force output to be grayscale, even if input is RGB.
'quality'	Set the quality of the compressed image to a value between 0 and 100 (default is 75). This only affects compression.
'optimize'	Perform Huffman table optimization. Takes longer, but results in smaller compressed image. This only affects compression.
'smooth'	Perform inter-block smoothing on uncompressed image. Only useful for low-quality images. This only affects decompression.

### See Also:

**JPEG Still Image Data Compression Standard** The canonical reference for the JPEG image format, by Pennebaker and Mitchell.

### Information Technology - Digital Compression and Coding of Continuous-tone Still Images - Requirements and Guidelines

The ISO standard for JPEG is also published as ITU T.81. This is available online in PDF form.

# SUNOS SPECIFIC SERVICES

The modules described in this chapter provide interfaces to features that are unique to SunOS 5 (also known as Solaris version 2).

## 39.1 `sunaudiodev` — Access to Sun audio hardware

*Platforms:* SunOS

Deprecated since version 2.6: The `sunaudiodev` module has been removed in Python 3. This module allows you to access the Sun audio interface. The Sun audio hardware is capable of recording and playing back audio data in u-LAW format with a sample rate of 8K per second. A full description can be found in the *audio(7I)* manual page.

The module `SUNAUDIODEV` defines constants which may be used with this module.

This module defines the following variables and functions:

### **exception** `sunaudiodev.error`

This exception is raised on all errors. The argument is a string describing what went wrong.

### `sunaudiodev.open(mode)`

This function opens the audio device and returns a Sun audio device object. This object can then be used to do I/O on. The *mode* parameter is one of `'r'` for record-only access, `'w'` for play-only access, `'rw'` for both and `'control'` for access to the control device. Since only one process is allowed to have the recorder or player open at the same time it is a good idea to open the device only for the activity needed. See *audio(7I)* for details.

As per the manpage, this module first looks in the environment variable `AUDIODEV` for the base audio device filename. If not found, it falls back to `/dev/audio`. The control device is calculated by appending `"ctl"` to the base audio device.

### 39.1.1 Audio Device Objects

The audio device objects are returned by `open()` define the following methods (except `control` objects which only provide `getinfo()`, `setinfo()`, `fileno()`, and `drain()`):

#### **audio device.close()**

This method explicitly closes the device. It is useful in situations where deleting the object does not immediately close it since there are other references to it. A closed device should not be used again.

#### **audio device.fileno()**

Returns the file descriptor associated with the device. This can be used to set up `SIGPOLL` notification, as described below.

**audio device.drain()**

This method waits until all pending output is processed and then returns. Calling this method is often not necessary: destroying the object will automatically close the audio device and this will do an implicit drain.

**audio device.flush()**

This method discards all pending output. It can be used avoid the slow response to a user's stop request (due to buffering of up to one second of sound).

**audio device.getinfo()**

This method retrieves status information like input and output volume, etc. and returns it in the form of an audio status object. This object has no methods but it contains a number of attributes describing the current device status. The names and meanings of the attributes are described in `<sun/audioio.h>` and in the *audio(7I)* manual page. Member names are slightly different from their C counterparts: a status object is only a single structure. Members of the `play` substructure have `o_` prepended to their name and members of the `record` structure have `i_`. So, the C member `play.sample_rate` is accessed as `o_sample_rate`, `record.gain` as `i_gain` and `monitor_gain` plainly as `monitor_gain`.

**audio device.ibufcount()**

This method returns the number of samples that are buffered on the recording side, i.e. the program will not block on a `read()` call of so many samples.

**audio device.obufcount()**

This method returns the number of samples buffered on the playback side. Unfortunately, this number cannot be used to determine a number of samples that can be written without blocking since the kernel output queue length seems to be variable.

**audio device.read(size)**

This method reads *size* samples from the audio input and returns them as a Python string. The function blocks until enough data is available.

**audio device.setinfo(status)**

This method sets the audio device status parameters. The *status* parameter is an device status object as returned by `getinfo()` and possibly modified by the program.

**audio device.write(samples)**

Write is passed a Python string containing audio samples to be played. If there is enough buffer space free it will immediately return, otherwise it will block.

The audio device supports asynchronous notification of various events, through the SIGPOLL signal. Here's an example of how you might enable this in Python:

```
def handle_sigpoll(signum, frame):
    print 'I got a SIGPOLL update'

import fcntl, signal, STROPTS

signal.signal(signal.SIGPOLL, handle_sigpoll)
fcntl.ioctl(audio_obj.fileno(), STROPTS.I_SETSIG, STROPTS.S_MSG)
```

## 39.2 SUNAUDIODEV — Constants used with sunaudiodev

*Platforms:* SunOS

Deprecated since version 2.6: The `SUNAUDIODEV` module has been removed in Python 3. This is a companion module to `sunaudiodev` which defines useful symbolic constants like `MIN_GAIN`, `MAX_GAIN`, `SPEAKER`, etc. The names of the constants are the same names as used in the C include file `<sun/audioio.h>`, with the leading string `AUDIO_` stripped.

# UNDOCUMENTED MODULES

Here's a quick listing of modules that are currently undocumented, but that should be documented. Feel free to contribute documentation for them! (Send via email to [docs@python.org](mailto:docs@python.org).)

The idea and original contents for this chapter were taken from a posting by Fredrik Lundh; the specific contents of this chapter have been substantially revised.

## 40.1 Miscellaneous useful utilities

Some of these are very old and/or not very robust; marked with “hmm.”

**ihooks** — Import hook support (for `rexec`; may become obsolete). Removed in Python 3.x.

## 40.2 Platform specific modules

These modules are used to implement the `os.path` module, and are not documented beyond this mention. There's little need to document these.

**ntpath** — Implementation of `os.path` on Win32, Win64, WinCE, and OS/2 platforms.

**posixpath** — Implementation of `os.path` on POSIX.

**bsddb185** — Backwards compatibility module for systems which still use the Berkeley DB 1.85 module. It is normally only available on certain BSD Unix-based systems. It should never be used directly.

## 40.3 Multimedia

**audiodev** — Platform-independent API for playing audio data. Removed in Python 3.x.

**linuxaudiodev** — Play audio data on the Linux audio device. Replaced in Python 2.3 by the `ossaudiodev` module. Removed in Python 3.x.

**sunaudio** — Interpret Sun audio headers (may become obsolete or a tool/demo). Removed in Python 3.x.

**toaiff** — Convert “arbitrary” sound files to AIFF files; should probably become a tool or demo. Requires the external program `sox`. Removed in Python 3.x.

## 40.4 Undocumented Mac OS modules

### 40.4.1 `applesingle` — AppleSingle decoder

*Platforms:* Mac

Deprecated since version 2.6.

### 40.4.2 `buildtools` — Helper module for BuildApplet and Friends

*Platforms:* Mac

Deprecated since version 2.4.

### 40.4.3 `cfmfile` — Code Fragment Resource module

*Platforms:* Mac

`cfmfile` is a module that understands Code Fragments and the accompanying “cfrg” resources. It can parse them and merge them, and is used by `BuildApplication` to combine all plugin modules to a single executable. Deprecated since version 2.4.

### 40.4.4 `icopen` — Internet Config replacement for `open()`

*Platforms:* Mac

Importing `icopen` will replace the built-in `open()` with a version that uses Internet Config to set file type and creator for new files. Deprecated since version 2.6.

### 40.4.5 `macerrors` — Mac OS Errors

*Platforms:* Mac

`macerrors` contains constant definitions for many Mac OS error codes. Deprecated since version 2.6.

### 40.4.6 `macresource` — Locate script resources

*Platforms:* Mac

`macresource` helps scripts finding their resources, such as dialogs and menus, without requiring special case code for when the script is run under MacPython, as a MacPython applet or under OSX Python. Deprecated since version 2.6.

### 40.4.7 `nav` — NavServices calls

*Platforms:* Mac

A low-level interface to Navigation Services. Deprecated since version 2.6.

#### 40.4.8 `PixmapWrapper` — Wrapper for `Pixmap` objects

*Platforms:* Mac

`PixmapWrapper` wraps a `Pixmap` object with a Python object that allows access to the fields by name. It also has methods to convert to and from `PIL` images. Deprecated since version 2.6.

#### 40.4.9 `videoreader` — Read QuickTime movies

*Platforms:* Mac

`videoreader` reads and decodes QuickTime movies and passes a stream of images to your program. It also provides some support for audio tracks. Deprecated since version 2.6.

#### 40.4.10 `w` — Widgets built on `Framework`

*Platforms:* Mac

The `w` widgets are used extensively in the `IDE`. Deprecated since version 2.6.

### 40.5 Obsolete

These modules are not normally available for import; additional work must be done to make them available.

These extension modules written in C are not built by default. Under Unix, these must be enabled by uncommenting the appropriate lines in `Modules/Setup` in the build tree and either rebuilding Python if the modules are statically linked, or building and installing the shared object if using dynamically-loaded extensions.

**`timing`** — Measure time intervals to high resolution (use `time.clock()` instead). Removed in Python 3.x.

### 40.6 SGI-specific Extension modules

The following are SGI specific, and may be out of touch with the current version of reality.

**`c1`** — Interface to the SGI compression library.

**`sv`** — Interface to the “simple video” board on SGI Indigo (obsolete hardware). Removed in Python 3.x.



---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**...** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3 - Automated Python 2 to 3 code translation*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator’s `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *Iterator Types*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *Dictionary view objects*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

# BIBLIOGRAPHY

[C99] ISO/IEC 9899:1999. “Programming languages – C.” A public draft of this standard is available at <http://www.open-std.org/jtc1/sc22/wg14/www/docs/n1256.pdf> .



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These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.2	2.1.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2.1	2.2	2002	PSF	yes
2.2.2	2.2.1	2002	PSF	yes
2.2.3	2.2.2	2002-2003	PSF	yes
2.3	2.2.2	2002-2003	PSF	yes
2.3.1	2.3	2002-2003	PSF	yes
2.3.2	2.3.1	2003	PSF	yes
2.3.3	2.3.2	2003	PSF	yes
2.3.4	2.3.3	2004	PSF	yes
2.3.5	2.3.4	2005	PSF	yes
2.4	2.3	2004	PSF	yes

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**Table C.1 – continued from previous page**

2.4.1	2.4	2005	PSF	yes
2.4.2	2.4.1	2005	PSF	yes
2.4.3	2.4.2	2006	PSF	yes
2.4.4	2.4.3	2006	PSF	yes
2.5	2.4	2006	PSF	yes
2.5.1	2.5	2007	PSF	yes
2.5.2	2.5.1	2008	PSF	yes
2.5.3	2.5.2	2008	PSF	yes
2.6	2.5	2008	PSF	yes
2.6.1	2.6	2008	PSF	yes
2.6.2	2.6.1	2009	PSF	yes
2.6.3	2.6.2	2009	PSF	yes
2.6.4	2.6.3	2010	PSF	yes
2.7	2.6	2010	PSF	yes

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The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

```
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```

```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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### C.3.4 MD5 message digest algorithm

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
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```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
           references to Ghostscript; clarified derivation from RFC 1321;
           now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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Modified by Jack Jansen, CWI, July 1995:

- Use `binascii` module to do the actual line-by-line conversion between `ascii` and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

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### C.3.16 zlib

The `zlib` extension is built using an included copy of the zlib sources if the zlib version found on the system is too old to be used for the build:

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Jean-loup Gailly  
jloup@gzip.org

Mark Adler  
madler@alumni.caltech.edu

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# The Python/C API

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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This manual documents the API used by C and C++ programmers who want to write extension modules or embed Python. It is a companion to *extending-index*, which describes the general principles of extension writing but does not document the API functions in detail.



# INTRODUCTION

The Application Programmer's Interface to Python gives C and C++ programmers access to the Python interpreter at a variety of levels. The API is equally usable from C++, but for brevity it is generally referred to as the Python/C API. There are two fundamentally different reasons for using the Python/C API. The first reason is to write *extension modules* for specific purposes; these are C modules that extend the Python interpreter. This is probably the most common use. The second reason is to use Python as a component in a larger application; this technique is generally referred to as *embedding* Python in an application.

Writing an extension module is a relatively well-understood process, where a “cookbook” approach works well. There are several tools that automate the process to some extent. While people have embedded Python in other applications since its early existence, the process of embedding Python is less straightforward than writing an extension.

Many API functions are useful independent of whether you're embedding or extending Python; moreover, most applications that embed Python will need to provide a custom extension as well, so it's probably a good idea to become familiar with writing an extension before attempting to embed Python in a real application.

## 1.1 Include Files

All function, type and macro definitions needed to use the Python/C API are included in your code by the following line:

```
#include "Python.h"
```

This implies inclusion of the following standard headers: `<stdio.h>`, `<string.h>`, `<errno.h>`, `<limits.h>`, `<assert.h>` and `<stdlib.h>` (if available).

---

**Note:** Since Python may define some pre-processor definitions which affect the standard headers on some systems, you *must* include `Python.h` before any standard headers are included.

---

All user visible names defined by `Python.h` (except those defined by the included standard headers) have one of the prefixes `Py` or `_Py`. Names beginning with `_Py` are for internal use by the Python implementation and should not be used by extension writers. Structure member names do not have a reserved prefix.

**Important:** user code should never define names that begin with `Py` or `_Py`. This confuses the reader, and jeopardizes the portability of the user code to future Python versions, which may define additional names beginning with one of these prefixes.

The header files are typically installed with Python. On Unix, these are located in the directories `prefix/include/pythonversion/` and `exec_prefix/include/pythonversion/`, where `prefix` and

`exec_prefix` are defined by the corresponding parameters to Python's **configure** script and `version` is `sys.version[:3]`. On Windows, the headers are installed in `prefix/include`, where `prefix` is the installation directory specified to the installer.

To include the headers, place both directories (if different) on your compiler's search path for includes. Do *not* place the parent directories on the search path and then use `#include <pythonX.Y/Python.h>`; this will break on multi-platform builds since the platform independent headers under

`prefix` include the platform specific headers from

`exec_prefix`.

C++ users should note that though the API is defined entirely using C, the header files do properly declare the entry points to be `extern "C"`, so there is no need to do anything special to use the API from C++.

## 1.2 Objects, Types and Reference Counts

Most Python/C API functions have one or more arguments as well as a return value of type `PyObject*`. This type is a pointer to an opaque data type representing an arbitrary Python object. Since all Python object types are treated the same way by the Python language in most situations (e.g., assignments, scope rules, and argument passing), it is only fitting that they should be represented by a single C type. Almost all Python objects live on the heap: you never declare an automatic or static variable of type `PyObject`, only pointer variables of type `PyObject*` can be declared. The sole exception are the type objects; since these must never be deallocated, they are typically static `PyTypeObject` objects.

All Python objects (even Python integers) have a *type* and a *reference count*. An object's type determines what kind of object it is (e.g., an integer, a list, or a user-defined function; there are many more as explained in *types*). For each of the well-known types there is a macro to check whether an object is of that type; for instance, `PyList_Check(a)` is true if (and only if) the object pointed to by `a` is a Python list.

### 1.2.1 Reference Counts

The reference count is important because today's computers have a finite (and often severely limited) memory size; it counts how many different places there are that have a reference to an object. Such a place could be another object, or a global (or static) C variable, or a local variable in some C function. When an object's reference count becomes zero, the object is deallocated. If it contains references to other objects, their reference count is decremented. Those other objects may be deallocated in turn, if this decrement makes their reference count become zero, and so on. (There's an obvious problem with objects that reference each other here; for now, the solution is "don't do that.")

Reference counts are always manipulated explicitly. The normal way is to use the macro `Py_INCREF()` to increment an object's reference count by one, and `Py_DECREF()` to decrement it by one. The `Py_DECREF()` macro is considerably more complex than the `Py_INCREF()` one, since it must check whether the reference count becomes zero and then cause the object's deallocator to be called. The deallocator is a function pointer contained in the object's type structure. The type-specific deallocator takes care of decrementing the reference counts for other objects contained in the object if this is a compound object type, such as a list, as well as performing any additional finalization that's needed. There's no chance that the reference count can overflow; at least as many bits are used to hold the reference count as there are distinct memory locations in virtual memory (assuming `sizeof(Py_ssize_t) >= sizeof(void*)`). Thus, the reference count increment is a simple operation.

It is not necessary to increment an object's reference count for every local variable that contains a pointer to an object. In theory, the object's reference count goes up by one when the variable is made to point to it and it goes down by one when the variable goes out of scope. However, these two cancel each other out, so at the end the reference count hasn't changed. The only real reason to use the reference count is to prevent the object from being deallocated as long as our variable is pointing to it. If we know that there is at least one other reference to the object that lives at least as long as our variable, there is no need to increment the reference count temporarily. An important situation where this

arises is in objects that are passed as arguments to C functions in an extension module that are called from Python; the call mechanism guarantees to hold a reference to every argument for the duration of the call.

However, a common pitfall is to extract an object from a list and hold on to it for a while without incrementing its reference count. Some other operation might conceivably remove the object from the list, decrementing its reference count and possibly deallocating it. The real danger is that innocent-looking operations may invoke arbitrary Python code which could do this; there is a code path which allows control to flow back to the user from a `Py_DECREF()`, so almost any operation is potentially dangerous.

A safe approach is to always use the generic operations (functions whose name begins with `PyObject_`, `PyNumber_`, `PySequence_` or `PyMapping_`). These operations always increment the reference count of the object they return. This leaves the caller with the responsibility to call `Py_DECREF()` when they are done with the result; this soon becomes second nature.

## Reference Count Details

The reference count behavior of functions in the Python/C API is best explained in terms of *ownership of references*. Ownership pertains to references, never to objects (objects are not owned: they are always shared). “Owning a reference” means being responsible for calling `Py_DECREF()` on it when the reference is no longer needed. Ownership can also be transferred, meaning that the code that receives ownership of the reference then becomes responsible for eventually decref’ing it by calling `Py_DECREF()` or `Py_XDECREF()` when it’s no longer needed—or passing on this responsibility (usually to its caller). When a function passes ownership of a reference on to its caller, the caller is said to receive a *new* reference. When no ownership is transferred, the caller is said to *borrow* the reference. Nothing needs to be done for a borrowed reference.

Conversely, when a calling function passes in a reference to an object, there are two possibilities: the function *steals* a reference to the object, or it does not. *Stealing a reference* means that when you pass a reference to a function, that function assumes that it now owns that reference, and you are not responsible for it any longer.

Few functions steal references; the two notable exceptions are `PyList_SetItem()` and `PyTuple_SetItem()`, which steal a reference to the item (but not to the tuple or list into which the item is put!). These functions were designed to steal a reference because of a common idiom for populating a tuple or list with newly created objects; for example, the code to create the tuple `(1, 2, "three")` could look like this (forgetting about error handling for the moment; a better way to code this is shown below):

```
PyObject *t;

t = PyTuple_New(3);
PyTuple_SetItem(t, 0, PyInt_FromLong(1L));
PyTuple_SetItem(t, 1, PyInt_FromLong(2L));
PyTuple_SetItem(t, 2, PyString_FromString("three"));
```

Here, `PyInt_FromLong()` returns a new reference which is immediately stolen by `PyTuple_SetItem()`. When you want to keep using an object although the reference to it will be stolen, use `Py_INCREF()` to grab another reference before calling the reference-stealing function.

Incidentally, `PyTuple_SetItem()` is the *only* way to set tuple items; `PySequence_SetItem()` and `PyObject_SetItem()` refuse to do this since tuples are an immutable data type. You should only use `PyTuple_SetItem()` for tuples that you are creating yourself.

Equivalent code for populating a list can be written using `PyList_New()` and `PyList_SetItem()`.

However, in practice, you will rarely use these ways of creating and populating a tuple or list. There’s a generic function, `Py_BuildValue()`, that can create most common objects from C values, directed by a *format string*. For example, the above two blocks of code could be replaced by the following (which also takes care of the error checking):

```
PyObject *tuple, *list;

tuple = Py_BuildValue("(iis)", 1, 2, "three");
list = Py_BuildValue("[iis]", 1, 2, "three");
```

It is much more common to use `PyObject_SetItem()` and friends with items whose references you are only borrowing, like arguments that were passed in to the function you are writing. In that case, their behaviour regarding reference counts is much saner, since you don't have to increment a reference count so you can give a reference away ("have it be stolen"). For example, this function sets all items of a list (actually, any mutable sequence) to a given item:

```
int
set_all(PyObject *target, PyObject *item)
{
    int i, n;

    n = PyObject_Length(target);
    if (n < 0)
        return -1;
    for (i = 0; i < n; i++) {
        PyObject *index = PyInt_FromLong(i);
        if (!index)
            return -1;
        if (PyObject_SetItem(target, index, item) < 0)
            return -1;
        Py_DECREF(index);
    }
    return 0;
}
```

The situation is slightly different for function return values. While passing a reference to most functions does not change your ownership responsibilities for that reference, many functions that return a reference to an object give you ownership of the reference. The reason is simple: in many cases, the returned object is created on the fly, and the reference you get is the only reference to the object. Therefore, the generic functions that return object references, like `PyObject_GetItem()` and `PySequence_GetItem()`, always return a new reference (the caller becomes the owner of the reference).

It is important to realize that whether you own a reference returned by a function depends on which function you call only — *the plumage* (the type of the object passed as an argument to the function) *doesn't enter into it!* Thus, if you extract an item from a list using `PyList_GetItem()`, you don't own the reference — but if you obtain the same item from the same list using `PySequence_GetItem()` (which happens to take exactly the same arguments), you do own a reference to the returned object.

Here is an example of how you could write a function that computes the sum of the items in a list of integers; once using `PyList_GetItem()`, and once using `PySequence_GetItem()`.

```
long
sum_list(PyObject *list)
{
    int i, n;
    long total = 0;
    PyObject *item;

    n = PyList_Size(list);
    if (n < 0)
        return -1; /* Not a list */
    for (i = 0; i < n; i++) {
        item = PyList_GetItem(list, i); /* Can't fail */
```

```

        if (!PyInt_Check(item)) continue; /* Skip non-integers */
        total += PyInt_AsLong(item);
    }
    return total;
}

long
sum_sequence(PyObject *sequence)
{
    int i, n;
    long total = 0;
    PyObject *item;
    n = PySequence_Length(sequence);
    if (n < 0)
        return -1; /* Has no length */
    for (i = 0; i < n; i++) {
        item = PySequence_GetItem(sequence, i);
        if (item == NULL)
            return -1; /* Not a sequence, or other failure */
        if (PyInt_Check(item))
            total += PyInt_AsLong(item);
        Py_DECREF(item); /* Discard reference ownership */
    }
    return total;
}

```

## 1.2.2 Types

There are few other data types that play a significant role in the Python/C API; most are simple C types such as `int`, `long`, `double` and `char*`. A few structure types are used to describe static tables used to list the functions exported by a module or the data attributes of a new object type, and another is used to describe the value of a complex number. These will be discussed together with the functions that use them.

## 1.3 Exceptions

The Python programmer only needs to deal with exceptions if specific error handling is required; unhandled exceptions are automatically propagated to the caller, then to the caller's caller, and so on, until they reach the top-level interpreter, where they are reported to the user accompanied by a stack traceback.

For C programmers, however, error checking always has to be explicit. All functions in the Python/C API can raise exceptions, unless an explicit claim is made otherwise in a function's documentation. In general, when a function encounters an error, it sets an exception, discards any object references that it owns, and returns an error indicator. If not documented otherwise, this indicator is either `NULL` or `-1`, depending on the function's return type. A few functions return a Boolean true/false result, with false indicating an error. Very few functions return no explicit error indicator or have an ambiguous return value, and require explicit testing for errors with `PyErr_Occurred()`. These exceptions are always explicitly documented.

Exception state is maintained in per-thread storage (this is equivalent to using global storage in an unthreaded application). A thread can be in one of two states: an exception has occurred, or not. The function `PyErr_Occurred()` can be used to check for this: it returns a borrowed reference to the exception type object when an exception has occurred, and `NULL` otherwise. There are a number of functions to set the exception state: `PyErr_SetString()` is the most common (though not the most general) function to set the exception state, and `PyErr_Clear()` clears the exception state.

The full exception state consists of three objects (all of which can be *NULL*): the exception type, the corresponding exception value, and the traceback. These have the same meanings as the Python objects `sys.exc_type`, `sys.exc_value`, and `sys.exc_traceback`; however, they are not the same: the Python objects represent the last exception being handled by a Python `try ... except` statement, while the C level exception state only exists while an exception is being passed on between C functions until it reaches the Python bytecode interpreter's main loop, which takes care of transferring it to `sys.exc_type` and friends.

Note that starting with Python 1.5, the preferred, thread-safe way to access the exception state from Python code is to call the function `sys.exc_info()`, which returns the per-thread exception state for Python code. Also, the semantics of both ways to access the exception state have changed so that a function which catches an exception will save and restore its thread's exception state so as to preserve the exception state of its caller. This prevents common bugs in exception handling code caused by an innocent-looking function overwriting the exception being handled; it also reduces the often unwanted lifetime extension for objects that are referenced by the stack frames in the traceback.

As a general principle, a function that calls another function to perform some task should check whether the called function raised an exception, and if so, pass the exception state on to its caller. It should discard any object references that it owns, and return an error indicator, but it should *not* set another exception — that would overwrite the exception that was just raised, and lose important information about the exact cause of the error.

A simple example of detecting exceptions and passing them on is shown in the `sum_sequence()` example above. It so happens that that example doesn't need to clean up any owned references when it detects an error. The following example function shows some error cleanup. First, to remind you why you like Python, we show the equivalent Python code:

```
def incr_item(dict, key):
    try:
        item = dict[key]
    except KeyError:
        item = 0
    dict[key] = item + 1
```

Here is the corresponding C code, in all its glory:

```
int
incr_item(PyObject *dict, PyObject *key)
{
    /* Objects all initialized to NULL for Py_XDECREF */
    PyObject *item = NULL, *const_one = NULL, *incremented_item = NULL;
    int rv = -1; /* Return value initialized to -1 (failure) */

    item = PyObject_GetItem(dict, key);
    if (item == NULL) {
        /* Handle KeyError only: */
        if (!PyErr_ExceptionMatches(PyExc_KeyError))
            goto error;

        /* Clear the error and use zero: */
        PyErr_Clear();
        item = PyInt_FromLong(0L);
        if (item == NULL)
            goto error;
    }
    const_one = PyInt_FromLong(1L);
    if (const_one == NULL)
        goto error;

    incremented_item = PyNumber_Add(item, const_one);
```

```

    if (incremented_item == NULL)
        goto error;

    if (PyObject_SetItem(dict, key, incremented_item) < 0)
        goto error;
    rv = 0; /* Success */
    /* Continue with cleanup code */

error:
    /* Cleanup code, shared by success and failure path */

    /* Use Py_XDECREF() to ignore NULL references */
    Py_XDECREF(item);
    Py_XDECREF(const_one);
    Py_XDECREF(incremented_item);

    return rv; /* -1 for error, 0 for success */
}

```

This example represents an endorsed use of the `goto` statement in C! It illustrates the use of `PyErr_ExceptionMatches()` and `PyErr_Clear()` to handle specific exceptions, and the use of `Py_XDECREF()` to dispose of owned references that may be `NULL` (note the 'X' in the name; `Py_DECREF()` would crash when confronted with a `NULL` reference). It is important that the variables used to hold owned references are initialized to `NULL` for this to work; likewise, the proposed return value is initialized to `-1` (failure) and only set to success after the final call made is successful.

## 1.4 Embedding Python

The one important task that only embedders (as opposed to extension writers) of the Python interpreter have to worry about is the initialization, and possibly the finalization, of the Python interpreter. Most functionality of the interpreter can only be used after the interpreter has been initialized.

The basic initialization function is `Py_Initialize()`. This initializes the table of loaded modules, and creates the fundamental modules `__builtin__`, `__main__`, `sys`, and `exceptions`. It also initializes the module search path (`sys.path`).

`Py_Initialize()` does not set the “script argument list” (`sys.argv`). If this variable is needed by Python code that will be executed later, it must be set explicitly with a call to `PySys_SetArgvEx(argc, argv, updatepath)` after the call to `Py_Initialize()`.

On most systems (in particular, on Unix and Windows, although the details are slightly different), `Py_Initialize()` calculates the module search path based upon its best guess for the location of the standard Python interpreter executable, assuming that the Python library is found in a fixed location relative to the Python interpreter executable. In particular, it looks for a directory named `lib/pythonX.Y` relative to the parent directory where the executable named `python` is found on the shell command search path (the environment variable `PATH`).

For instance, if the Python executable is found in `/usr/local/bin/python`, it will assume that the libraries are in `/usr/local/lib/pythonX.Y`. (In fact, this particular path is also the “fallback” location, used when no executable file named `python` is found along `PATH`.) The user can override this behavior by setting the environment variable `PYTHONHOME`, or insert additional directories in front of the standard path by setting `PYTHONPATH`.

The embedding application can steer the search by calling `Py_SetProgramName(file)` *before* calling `Py_Initialize()`. Note that

`PYTHONHOME` still overrides this and `PYTHONPATH` is still inserted in front of the standard path. An application that requires total control has to provide its own implementation of `Py_GetPath()`, `Py_GetPrefix()`,

`Py_GetExecPrefix()`, and `Py_GetProgramFullPath()` (all defined in `Modules/getpath.c`).

Sometimes, it is desirable to “uninitialize” Python. For instance, the application may want to start over (make another call to `Py_Initialize()`) or the application is simply done with its use of Python and wants to free memory allocated by Python. This can be accomplished by calling `Py_Finalize()`. The function `Py_IsInitialized()` returns true if Python is currently in the initialized state. More information about these functions is given in a later chapter. Notice that `Py_Finalize()` does *not* free all memory allocated by the Python interpreter, e.g. memory allocated by extension modules currently cannot be released.

## 1.5 Debugging Builds

Python can be built with several macros to enable extra checks of the interpreter and extension modules. These checks tend to add a large amount of overhead to the runtime so they are not enabled by default.

A full list of the various types of debugging builds is in the file `Misc/SpecialBuilds.txt` in the Python source distribution. Builds are available that support tracing of reference counts, debugging the memory allocator, or low-level profiling of the main interpreter loop. Only the most frequently-used builds will be described in the remainder of this section.

Compiling the interpreter with the `Py_DEBUG` macro defined produces what is generally meant by “a debug build” of Python. `Py_DEBUG` is enabled in the Unix build by adding `--with-pydebug` to the `./configure` command. It is also implied by the presence of the not-Python-specific `_DEBUG` macro. When `Py_DEBUG` is enabled in the Unix build, compiler optimization is disabled.

In addition to the reference count debugging described below, the following extra checks are performed:

- Extra checks are added to the object allocator.
- Extra checks are added to the parser and compiler.
- Downcasts from wide types to narrow types are checked for loss of information.
- A number of assertions are added to the dictionary and set implementations. In addition, the set object acquires a `test_c_api()` method.
- Sanity checks of the input arguments are added to frame creation.
- The storage for long ints is initialized with a known invalid pattern to catch reference to uninitialized digits.
- Low-level tracing and extra exception checking are added to the runtime virtual machine.
- Extra checks are added to the memory arena implementation.
- Extra debugging is added to the thread module.

There may be additional checks not mentioned here.

Defining `Py_TRACE_REFS` enables reference tracing. When defined, a circular doubly linked list of active objects is maintained by adding two extra fields to every `PyObject`. Total allocations are tracked as well. Upon exit, all existing references are printed. (In interactive mode this happens after every statement run by the interpreter.) Implied by `Py_DEBUG`.

Please refer to `Misc/SpecialBuilds.txt` in the Python source distribution for more detailed information.

# THE VERY HIGH LEVEL LAYER

The functions in this chapter will let you execute Python source code given in a file or a buffer, but they will not let you interact in a more detailed way with the interpreter.

Several of these functions accept a start symbol from the grammar as a parameter. The available start symbols are `Py_eval_input`, `Py_file_input`, and `Py_single_input`. These are described following the functions which accept them as parameters.

Note also that several of these functions take `FILE*` parameters. One particular issue which needs to be handled carefully is that the `FILE` structure for different C libraries can be different and incompatible. Under Windows (at least), it is possible for dynamically linked extensions to actually use different libraries, so care should be taken that `FILE*` parameters are only passed to these functions if it is certain that they were created by the same library that the Python runtime is using.

**int `Py_Main`** (int *argc*, char *\*\*argv*)

The main program for the standard interpreter. This is made available for programs which embed Python. The *argc* and *argv* parameters should be prepared exactly as those which are passed to a C program's `main()` function. It is important to note that the argument list may be modified (but the contents of the strings pointed to by the argument list are not). The return value will be 0 if the interpreter exits normally (ie, without an exception), 1 if the interpreter exits due to an exception, or 2 if the parameter list does not represent a valid Python command line.

Note that if an otherwise unhandled `SystemExit` is raised, this function will not return 1, but exit the process, as long as `Py_InspectFlag` is not set.

**int `PyRun_AnyFile`** (FILE *\*fp*, const char *\*filename*)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving *closeit* set to 0 and *flags* set to `NULL`.

**int `PyRun_AnyFileFlags`** (FILE *\*fp*, const char *\*filename*, `PyCompilerFlags` *\*flags*)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving the *closeit* argument set to 0.

**int `PyRun_AnyFileEx`** (FILE *\*fp*, const char *\*filename*, int *closeit*)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving the *flags* argument set to `NULL`.

**int `PyRun_AnyFileExFlags`** (FILE *\*fp*, const char *\*filename*, int *closeit*, `PyCompilerFlags` *\*flags*)

If *fp* refers to a file associated with an interactive device (console or terminal input or Unix pseudo-terminal), return the value of `PyRun_InteractiveLoop()`, otherwise return the result of `PyRun_SimpleFile()`. If *filename* is `NULL`, this function uses "???" as the filename.

**int `PyRun_SimpleString`** (const char *\*command*)

This is a simplified interface to `PyRun_SimpleStringFlags()` below, leaving the `PyCompilerFlags*` argument set to `NULL`.

**int `PyRun_SimpleStringFlags`** (const char *\*command*, `PyCompilerFlags` *\*flags*)

Executes the Python source code from *command* in the `__main__` module according to the *flags* argument. If

`__main__` does not already exist, it is created. Returns 0 on success or -1 if an exception was raised. If there was an error, there is no way to get the exception information. For the meaning of *flags*, see below.

Note that if an otherwise unhandled `SystemExit` is raised, this function will not return -1, but exit the process, as long as `Py_InspectFlag` is not set.

int **PyRun\_SimpleFile** (FILE \*fp, const char \*filename)

This is a simplified interface to `PyRun_SimpleFileExFlags()` below, leaving *closeit* set to 0 and *flags* set to `NULL`.

int **PyRun\_SimpleFileFlags** (FILE \*fp, const char \*filename, PyCompilerFlags \*flags)

This is a simplified interface to `PyRun_SimpleFileExFlags()` below, leaving *closeit* set to 0.

int **PyRun\_SimpleFileEx** (FILE \*fp, const char \*filename, int closeit)

This is a simplified interface to `PyRun_SimpleFileExFlags()` below, leaving *flags* set to `NULL`.

int **PyRun\_SimpleFileExFlags** (FILE \*fp, const char \*filename, int closeit, PyCompilerFlags \*flags)

Similar to `PyRun_SimpleStringFlags()`, but the Python source code is read from *fp* instead of an in-memory string. *filename* should be the name of the file. If *closeit* is true, the file is closed before `PyRun_SimpleFileExFlags` returns.

int **PyRun\_InteractiveOne** (FILE \*fp, const char \*filename)

This is a simplified interface to `PyRun_InteractiveOneFlags()` below, leaving *flags* set to `NULL`.

int **PyRun\_InteractiveOneFlags** (FILE \*fp, const char \*filename, PyCompilerFlags \*flags)

Read and execute a single statement from a file associated with an interactive device according to the *flags* argument. The user will be prompted using `sys.ps1` and `sys.ps2`. Returns 0 when the input was executed successfully, -1 if there was an exception, or an error code from the `errcode.h` include file distributed as part of Python if there was a parse error. (Note that `errcode.h` is not included by `Python.h`, so must be included specifically if needed.)

int **PyRun\_InteractiveLoop** (FILE \*fp, const char \*filename)

This is a simplified interface to `PyRun_InteractiveLoopFlags()` below, leaving *flags* set to `NULL`.

int **PyRun\_InteractiveLoopFlags** (FILE \*fp, const char \*filename, PyCompilerFlags \*flags)

Read and execute statements from a file associated with an interactive device until EOF is reached. The user will be prompted using `sys.ps1` and `sys.ps2`. Returns 0 at EOF.

struct \_node\* **PyParser\_SimpleParseString** (const char \*str, int start)

This is a simplified interface to `PyParser_SimpleParseStringFlagsFilename()` below, leaving *filename* set to `NULL` and *flags* set to 0.

struct \_node\* **PyParser\_SimpleParseStringFlags** (const char \*str, int start, int flags)

This is a simplified interface to `PyParser_SimpleParseStringFlagsFilename()` below, leaving *filename* set to `NULL`.

struct \_node\* **PyParser\_SimpleParseStringFlagsFilename** (const char \*str, const char \*filename, int start, int flags)

Parse Python source code from *str* using the start token *start* according to the *flags* argument. The result can be used to create a code object which can be evaluated efficiently. This is useful if a code fragment must be evaluated many times.

struct \_node\* **PyParser\_SimpleParseFile** (FILE \*fp, const char \*filename, int start)

This is a simplified interface to `PyParser_SimpleParseFileFlags()` below, leaving *flags* set to 0

struct \_node\* **PyParser\_SimpleParseFileFlags** (FILE \*fp, const char \*filename, int start, int flags)

Similar to `PyParser_SimpleParseStringFlagsFilename()`, but the Python source code is read from *fp* instead of an in-memory string.

PyObject\* **PyRun\_String** (const char \*str, int start, PyObject \*globals, PyObject \*locals)

Return value: New reference.

This is a simplified interface to `PyRun_StringFlags()` below, leaving *flags* set to `NULL`.

**PyObject\* PyRun\_StringFlags** (const char \*str, int start, PyObject \*globals, PyObject \*locals, PyCompilerFlags \*flags)

*Return value:* New reference.

Execute Python source code from *str* in the context specified by the dictionaries *globals* and *locals* with the compiler flags specified by *flags*. The parameter *start* specifies the start token that should be used to parse the source code.

Returns the result of executing the code as a Python object, or *NULL* if an exception was raised.

**PyObject\* PyRun\_File** (FILE \*fp, const char \*filename, int start, PyObject \*globals, PyObject \*locals)

*Return value:* New reference.

This is a simplified interface to `PyRun_FileExFlags()` below, leaving *closeit* set to 0 and *flags* set to *NULL*.

**PyObject\* PyRun\_FileEx** (FILE \*fp, const char \*filename, int start, PyObject \*globals, PyObject \*locals, int closeit)

*Return value:* New reference.

This is a simplified interface to `PyRun_FileExFlags()` below, leaving *flags* set to *NULL*.

**PyObject\* PyRun\_FileFlags** (FILE \*fp, const char \*filename, int start, PyObject \*globals, PyObject \*locals, PyCompilerFlags \*flags)

*Return value:* New reference.

This is a simplified interface to `PyRun_FileExFlags()` below, leaving *closeit* set to 0.

**PyObject\* PyRun\_FileExFlags** (FILE \*fp, const char \*filename, int start, PyObject \*globals, PyObject \*locals, int closeit, PyCompilerFlags \*flags)

*Return value:* New reference.

Similar to `PyRun_StringFlags()`, but the Python source code is read from *fp* instead of an in-memory string. *filename* should be the name of the file. If *closeit* is true, the file is closed before `PyRun_FileExFlags()` returns.

**PyObject\* Py\_CompileString** (const char \*str, const char \*filename, int start)

*Return value:* New reference.

This is a simplified interface to `Py_CompileStringFlags()` below, leaving *flags* set to *NULL*.

**PyObject\* Py\_CompileStringFlags** (const char \*str, const char \*filename, int start, PyCompilerFlags \*flags)

*Return value:* New reference.

Parse and compile the Python source code in *str*, returning the resulting code object. The start token is given by *start*; this can be used to constrain the code which can be compiled and should be `Py_eval_input`, `Py_file_input`, or `Py_single_input`. The filename specified by *filename* is used to construct the code object and may appear in tracebacks or `SyntaxError` exception messages. This returns *NULL* if the code cannot be parsed or compiled.

**PyObject\* PyEval\_EvalCode** (PyCodeObject \*co, PyObject \*globals, PyObject \*locals)

*Return value:* New reference.

This is a simplified interface to `PyEval_EvalCodeEx()`, with just the code object, and the dictionaries of global and local variables. The other arguments are set to *NULL*.

**PyObject\* PyEval\_EvalCodeEx** (PyCodeObject \*co, PyObject \*globals, PyObject \*locals, PyObject \*\*args, int argcount, PyObject \*\*kws, int kwcount, PyObject \*\*defs, int defcount, PyObject \*closure)

Evaluate a precompiled code object, given a particular environment for its evaluation. This environment consists of dictionaries of global and local variables, arrays of arguments, keywords and defaults, and a closure tuple of cells.

**PyObject\* PyEval\_EvalFrame** (PyFrameObject \*f)

Evaluate an execution frame. This is a simplified interface to `PyEval_EvalFrameEx`, for backward compatibility.

**PyObject\* PyEval\_EvalFrameEx** (PyFrameObject \*f, int throwflag)

This is the main, unvarnished function of Python interpretation. It is literally 2000 lines long. The code object associated with the execution frame *f* is executed, interpreting bytecode and executing calls as needed. The additional *throwflag* parameter can mostly be ignored - if true, then it causes an exception to immediately be thrown; this is used for the `throw()` methods of generator objects.

int **PyEval\_MergeCompilerFlags** (`PyCompilerFlags *cf`)

This function changes the flags of the current evaluation frame, and returns true on success, false on failure.

int **Py\_eval\_input**

The start symbol from the Python grammar for isolated expressions; for use with `Py_CompileString()`.

int **Py\_file\_input**

The start symbol from the Python grammar for sequences of statements as read from a file or other source; for use with `Py_CompileString()`. This is the symbol to use when compiling arbitrarily long Python source code.

int **Py\_single\_input**

The start symbol from the Python grammar for a single statement; for use with `Py_CompileString()`. This is the symbol used for the interactive interpreter loop.

struct **PyCompilerFlags**

This is the structure used to hold compiler flags. In cases where code is only being compiled, it is passed as `int flags`, and in cases where code is being executed, it is passed as `PyCompilerFlags *flags`. In this case, `from __future__ import` can modify *flags*.

Whenever `PyCompilerFlags *flags` is *NULL*, `cf_flags` is treated as equal to 0, and any modification due to `from __future__ import` is discarded.

```
struct PyCompilerFlags {
    int cf_flags;
}
```

int **CO\_FUTURE\_DIVISION**

This bit can be set in *flags* to cause division operator `/` to be interpreted as “true division” according to [PEP 238](#).

# REFERENCE COUNTING

The macros in this section are used for managing reference counts of Python objects.

void **Py\_INCREF** (PyObject \*o)

Increment the reference count for object *o*. The object must not be *NULL*; if you aren't sure that it isn't *NULL*, use `Py_XINCREF ()`.

void **Py\_XINCREF** (PyObject \*o)

Increment the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect.

void **Py\_DECREF** (PyObject \*o)

Decrement the reference count for object *o*. The object must not be *NULL*; if you aren't sure that it isn't *NULL*, use `Py_XDECREF ()`. If the reference count reaches zero, the object's type's deallocation function (which must not be *NULL*) is invoked.

**Warning:** The deallocation function can cause arbitrary Python code to be invoked (e.g. when a class instance with a `__del__ ()` method is deallocated). While exceptions in such code are not propagated, the executed code has free access to all Python global variables. This means that any object that is reachable from a global variable should be in a consistent state before `Py_DECREF ()` is invoked. For example, code to delete an object from a list should copy a reference to the deleted object in a temporary variable, update the list data structure, and then call `Py_DECREF ()` for the temporary variable.

void **Py\_XDECREF** (PyObject \*o)

Decrement the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for `Py_DECREF ()`, and the same warning applies.

void **Py\_CLEAR** (PyObject \*o)

Decrement the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for `Py_DECREF ()`, except that the argument is also set to *NULL*. The warning for `Py_DECREF ()` does not apply with respect to the object passed because the macro carefully uses a temporary variable and sets the argument to *NULL* before decrementing its reference count.

It is a good idea to use this macro whenever decrementing the value of a variable that might be traversed during garbage collection. New in version 2.4.

The following functions are for runtime dynamic embedding of Python: `Py_IncRef (PyObject *o)`, `Py_DecRef (PyObject *o)`. They are simply exported function versions of `Py_XINCREF ()` and `Py_XDECREF ()`, respectively.

The following functions or macros are only for use within the interpreter core: `_Py_Dealloc ()`, `_Py_ForgetReference ()`, `_Py_NewReference ()`, as well as the global variable `_Py_RefTotal`.



# EXCEPTION HANDLING

The functions described in this chapter will let you handle and raise Python exceptions. It is important to understand some of the basics of Python exception handling. It works somewhat like the Unix `errno` variable: there is a global indicator (per thread) of the last error that occurred. Most functions don't clear this on success, but will set it to indicate the cause of the error on failure. Most functions also return an error indicator, usually `NULL` if they are supposed to return a pointer, or `-1` if they return an integer (exception: the `PyArg_*()` functions return 1 for success and 0 for failure).

When a function must fail because some function it called failed, it generally doesn't set the error indicator; the function it called already set it. It is responsible for either handling the error and clearing the exception or returning after cleaning up any resources it holds (such as object references or memory allocations); it should *not* continue normally if it is not prepared to handle the error. If returning due to an error, it is important to indicate to the caller that an error has been set. If the error is not handled or carefully propagated, additional calls into the Python/C API may not behave as intended and may fail in mysterious ways.

The error indicator consists of three Python objects corresponding to the Python variables `sys.exc_type`, `sys.exc_value` and `sys.exc_traceback`. API functions exist to interact with the error indicator in various ways. There is a separate error indicator for each thread.

void **PyErr\_PrintEx** (int *set\_sys\_last\_vars*)

Print a standard traceback to `sys.stderr` and clear the error indicator. Call this function only when the error indicator is set. (Otherwise it will cause a fatal error!)

If *set\_sys\_last\_vars* is nonzero, the variables `sys.last_type`, `sys.last_value` and `sys.last_traceback` will be set to the type, value and traceback of the printed exception, respectively.

void **PyErr\_Print** ()

Alias for `PyErr_PrintEx(1)`.

**PyObject\*** **PyErr\_Occurred** ()

*Return value: Borrowed reference.*

Test whether the error indicator is set. If set, return the exception *type* (the first argument to the last call to one of the `PyErr_Set*()` functions or to `PyErr_Restore()`). If not set, return `NULL`. You do not own a reference to the return value, so you do not need to `Py_DECREF()` it.

---

**Note:** Do not compare the return value to a specific exception; use `PyErr_ExceptionMatches()` instead, shown below. (The comparison could easily fail since the exception may be an instance instead of a class, in the case of a class exception, or it may be a subclass of the expected exception.)

---

int **PyErr\_ExceptionMatches** (PyObject \**exc*)

Equivalent to `PyErr_GivenExceptionMatches(PyErr_Occurred(), exc)`. This should only be called when an exception is actually set; a memory access violation will occur if no exception has been raised.

int **PyErr\_GivenExceptionMatches** (PyObject \*given, PyObject \*exc)

Return true if the *given* exception matches the exception in *exc*. If *exc* is a class object, this also returns true when *given* is an instance of a subclass. If *exc* is a tuple, all exceptions in the tuple (and recursively in subtuples) are searched for a match.

void **PyErr\_NormalizeException** (PyObject\*\*exc, PyObject\*\*val, PyObject\*\*tb)

Under certain circumstances, the values returned by `PyErr_Fetch()` below can be “unnormalized”, meaning that \*exc is a class object but \*val is not an instance of the same class. This function can be used to instantiate the class in that case. If the values are already normalized, nothing happens. The delayed normalization is implemented to improve performance.

void **PyErr\_Clear** ()

Clear the error indicator. If the error indicator is not set, there is no effect.

void **PyErr\_Fetch** (PyObject \*\*ptype, PyObject \*\*pvalue, PyObject \*\*ptraceback)

Retrieve the error indicator into three variables whose addresses are passed. If the error indicator is not set, set all three variables to *NULL*. If it is set, it will be cleared and you own a reference to each object retrieved. The value and traceback object may be *NULL* even when the type object is not.

---

**Note:** This function is normally only used by code that needs to handle exceptions or by code that needs to save and restore the error indicator temporarily.

---

void **PyErr\_Restore** (PyObject \*type, PyObject \*value, PyObject \*traceback)

Set the error indicator from the three objects. If the error indicator is already set, it is cleared first. If the objects are *NULL*, the error indicator is cleared. Do not pass a *NULL* type and non-*NULL* value or traceback. The exception type should be a class. Do not pass an invalid exception type or value. (Violating these rules will cause subtle problems later.) This call takes away a reference to each object: you must own a reference to each object before the call and after the call you no longer own these references. (If you don’t understand this, don’t use this function. I warned you.)

---

**Note:** This function is normally only used by code that needs to save and restore the error indicator temporarily; use `PyErr_Fetch()` to save the current exception state.

---

void **PyErr\_SetString** (PyObject \*type, const char \*message)

This is the most common way to set the error indicator. The first argument specifies the exception type; it is normally one of the standard exceptions, e.g. `PyExc_RuntimeError`. You need not increment its reference count. The second argument is an error message; it is converted to a string object.

void **PyErr\_SetObject** (PyObject \*type, PyObject \*value)

This function is similar to `PyErr_SetString()` but lets you specify an arbitrary Python object for the “value” of the exception.

PyObject\* **PyErr\_Format** (PyObject \*exception, const char \*format, ...)

*Return value:* Always *NULL*.

This function sets the error indicator and returns *NULL*. *exception* should be a Python exception class. The *format* and subsequent parameters help format the error message; they have the same meaning and values as in `PyString_FromFormat()`.

void **PyErr\_SetNone** (PyObject \*type)

This is a shorthand for `PyErr_SetObject(type, Py_None)`.

int **PyErr\_BadArgument** ()

This is a shorthand for `PyErr_SetString(PyExc_TypeError, message)`, where *message* indicates that a built-in operation was invoked with an illegal argument. It is mostly for internal use.

PyObject\* **PyErr\_NoMemory** ()

*Return value:* Always *NULL*.

This is a shorthand for `PyErr_SetNone(PyExc_MemoryError)`; it returns `NULL` so an object allocation function can write `return PyErr_NoMemory()`; when it runs out of memory.

**PyObject\*** `PyErr_SetFromErrno(PyObject *type)`

*Return value:* Always `NULL`.

This is a convenience function to raise an exception when a C library function has returned an error and set the C variable `errno`. It constructs a tuple object whose first item is the integer `errno` value and whose second item is the corresponding error message (gotten from `strerror()`), and then calls `PyErr_SetObject(type, object)`. On Unix, when the `errno` value is `EINTR`, indicating an interrupted system call, this calls `PyErr_CheckSignals()`, and if that set the error indicator, leaves it set to that. The function always returns `NULL`, so a wrapper function around a system call can write `return PyErr_SetFromErrno(type)`; when the system call returns an error.

**PyObject\*** `PyErr_SetFromErrnoWithFilename(PyObject *type, const char *filename)`

*Return value:* Always `NULL`.

Similar to `PyErr_SetFromErrno()`, with the additional behavior that if `filename` is not `NULL`, it is passed to the constructor of `type` as a third parameter. In the case of exceptions such as `IOError` and `OSError`, this is used to define the `filename` attribute of the exception instance.

**PyObject\*** `PyErr_SetFromWindowsErr(int ierr)`

*Return value:* Always `NULL`.

This is a convenience function to raise `WindowsError`. If called with `ierr` of 0, the error code returned by a call to `GetLastError()` is used instead. It calls the Win32 function `FormatMessage()` to retrieve the Windows description of error code given by `ierr` or `GetLastError()`, then it constructs a tuple object whose first item is the `ierr` value and whose second item is the corresponding error message (gotten from `FormatMessage()`), and then calls `PyErr_SetObject(PyExc_WindowsError, object)`. This function always returns `NULL`. Availability: Windows.

**PyObject\*** `PyErr_SetExcFromWindowsErr(PyObject *type, int ierr)`

*Return value:* Always `NULL`.

Similar to `PyErr_SetFromWindowsErr()`, with an additional parameter specifying the exception type to be raised. Availability: Windows. New in version 2.3.

**PyObject\*** `PyErr_SetFromWindowsErrWithFilename(int ierr, const char *filename)`

*Return value:* Always `NULL`.

Similar to `PyErr_SetFromWindowsErr()`, with the additional behavior that if `filename` is not `NULL`, it is passed to the constructor of `WindowsError` as a third parameter. Availability: Windows.

**PyObject\*** `PyErr_SetExcFromWindowsErrWithFilename(PyObject *type, int ierr, char *filename)`

*Return value:* Always `NULL`.

Similar to `PyErr_SetFromWindowsErrWithFilename()`, with an additional parameter specifying the exception type to be raised. Availability: Windows. New in version 2.3.

**void** `PyErr_BadInternalCall()`

This is a shorthand for `PyErr_SetString(PyExc_SystemError, message)`, where `message` indicates that an internal operation (e.g. a Python/C API function) was invoked with an illegal argument. It is mostly for internal use.

**int** `PyErr_WarnEx(PyObject *category, char *message, int stacklevel)`

Issue a warning message. The `category` argument is a warning category (see below) or `NULL`; the `message` argument is a message string. `stacklevel` is a positive number giving a number of stack frames; the warning will be issued from the currently executing line of code in that stack frame. A `stacklevel` of 1 is the function calling `PyErr_WarnEx()`, 2 is the function above that, and so forth.

This function normally prints a warning message to `sys.stderr`; however, it is also possible that the user has specified that warnings are to be turned into errors, and in that case this will raise an exception. It is also possible that the function raises an exception because of a problem with the warning machinery (the implementation imports the `warnings` module to do the heavy lifting). The return value is 0 if no exception is raised, or -1

if an exception is raised. (It is not possible to determine whether a warning message is actually printed, nor what the reason is for the exception; this is intentional.) If an exception is raised, the caller should do its normal exception handling (for example, `Py_DECREF()` owned references and return an error value).

Warning categories must be subclasses of `Warning`; the default warning category is `RuntimeWarning`. The standard Python warning categories are available as global variables whose names are `PyExc_` followed by the Python exception name. These have the type `PyObject*`; they are all class objects. Their names are `PyExc_Warning`, `PyExc_UserWarning`, `PyExc_UnicodeWarning`, `PyExc_DeprecationWarning`, `PyExc_SyntaxWarning`, `PyExc_RuntimeWarning`, and `PyExc_FutureWarning`. `PyExc_Warning` is a subclass of `PyExc_Exception`; the other warning categories are subclasses of `PyExc_Warning`.

For information about warning control, see the documentation for the `warnings` module and the `-W` option in the command line documentation. There is no C API for warning control.

`int PyErr_Warn(PyObject *category, char *message)`

Issue a warning message. The *category* argument is a warning category (see below) or `NULL`; the *message* argument is a message string. The warning will appear to be issued from the function calling `PyErr_Warn()`, equivalent to calling `PyErr_WarnEx()` with a *stacklevel* of 1.

Deprecated; use `PyErr_WarnEx()` instead.

`int PyErr_WarnExplicit(PyObject *category, const char *message, const char *filename, int lineno, const char *module, PyObject *registry)`

Issue a warning message with explicit control over all warning attributes. This is a straightforward wrapper around the Python function `warnings.warn_explicit()`, see there for more information. The *module* and *registry* arguments may be set to `NULL` to get the default effect described there.

`int PyErr_WarnPy3k(char *message, int stacklevel)`

Issue a `DeprecationWarning` with the given *message* and *stacklevel* if the `Py_Py3kWarningFlag` flag is enabled. New in version 2.6.

`int PyErr_CheckSignals()`

This function interacts with Python's signal handling. It checks whether a signal has been sent to the processes and if so, invokes the corresponding signal handler. If the `signal` module is supported, this can invoke a signal handler written in Python. In all cases, the default effect for `SIGINT` is to raise the `KeyboardInterrupt` exception. If an exception is raised the error indicator is set and the function returns `-1`; otherwise the function returns `0`. The error indicator may or may not be cleared if it was previously set.

`void PyErr_SetInterrupt()`

This function simulates the effect of a `SIGINT` signal arriving — the next time `PyErr_CheckSignals()` is called, `KeyboardInterrupt` will be raised. It may be called without holding the interpreter lock.

`int PySignal_SetWakeupFd(int fd)`

This utility function specifies a file descriptor to which a `'\0'` byte will be written whenever a signal is received. It returns the previous such file descriptor. The value `-1` disables the feature; this is the initial state. This is equivalent to `signal.set_wakeup_fd()` in Python, but without any error checking. *fd* should be a valid file descriptor. The function should only be called from the main thread. New in version 2.6.

`PyObject* PyErr_NewException(char *name, PyObject *base, PyObject *dict)`

*Return value:* New reference.

This utility function creates and returns a new exception class. The *name* argument must be the name of the new exception, a C string of the form `module.classname`. The *base* and *dict* arguments are normally `NULL`. This creates a class object derived from `Exception` (accessible in C as `PyExc_Exception`).

The `__module__` attribute of the new class is set to the first part (up to the last dot) of the *name* argument, and the class name is set to the last part (after the last dot). The *base* argument can be used to specify alternate base classes; it can either be only one class or a tuple of classes. The *dict* argument can be used to specify a dictionary of class variables and methods.

**PyObject\*** **PyErr\_NewExceptionWithDoc** (char \*name, char \*doc, PyObject \*base, PyObject \*dict)

Return value: New reference.

Same as `PyErr_NewException()`, except that the new exception class can easily be given a docstring: If *doc* is non-*NULL*, it will be used as the docstring for the exception class. New in version 2.7.

void **PyErr\_WriteUnraisable** (PyObject \*obj)

This utility function prints a warning message to `sys.stderr` when an exception has been set but it is impossible for the interpreter to actually raise the exception. It is used, for example, when an exception occurs in an `__del__()` method.

The function is called with a single argument *obj* that identifies the context in which the unraisable exception occurred. The repr of *obj* will be printed in the warning message.

## 4.1 Unicode Exception Objects

The following functions are used to create and modify Unicode exceptions from C.

**PyObject\*** **PyUnicodeDecodeError\_Create** (const char \*encoding, const char \*object, Py\_ssize\_t length, Py\_ssize\_t start, Py\_ssize\_t end, const char \*reason)

Create a `UnicodeDecodeError` object with the attributes *encoding*, *object*, *length*, *start*, *end* and *reason*.

**PyObject\*** **PyUnicodeEncodeError\_Create** (const char \*encoding, const Py\_UNICODE \*object, Py\_ssize\_t length, Py\_ssize\_t start, Py\_ssize\_t end, const char \*reason)

Create a `UnicodeEncodeError` object with the attributes *encoding*, *object*, *length*, *start*, *end* and *reason*.

**PyObject\*** **PyUnicodeTranslateError\_Create** (const Py\_UNICODE \*object, Py\_ssize\_t length, Py\_ssize\_t start, Py\_ssize\_t end, const char \*reason)

Create a `UnicodeTranslateError` object with the attributes *object*, *length*, *start*, *end* and *reason*.

**PyObject\*** **PyUnicodeDecodeError\_GetEncoding** (PyObject \*exc)

**PyObject\*** **PyUnicodeEncodeError\_GetEncoding** (PyObject \*exc)

Return the *encoding* attribute of the given exception object.

**PyObject\*** **PyUnicodeDecodeError\_GetObject** (PyObject \*exc)

**PyObject\*** **PyUnicodeEncodeError\_GetObject** (PyObject \*exc)

**PyObject\*** **PyUnicodeTranslateError\_GetObject** (PyObject \*exc)

Return the *object* attribute of the given exception object.

int **PyUnicodeDecodeError\_GetStart** (PyObject \*exc, Py\_ssize\_t \*start)

int **PyUnicodeEncodeError\_GetStart** (PyObject \*exc, Py\_ssize\_t \*start)

int **PyUnicodeTranslateError\_GetStart** (PyObject \*exc, Py\_ssize\_t \*start)

Get the *start* attribute of the given exception object and place it into \*start. *start* must not be *NULL*. Return 0 on success, -1 on failure.

int **PyUnicodeDecodeError\_SetStart** (PyObject \*exc, Py\_ssize\_t start)

int **PyUnicodeEncodeError\_SetStart** (PyObject \*exc, Py\_ssize\_t start)

int **PyUnicodeTranslateError\_SetStart** (PyObject \*exc, Py\_ssize\_t start)

Set the *start* attribute of the given exception object to *start*. Return 0 on success, -1 on failure.

int **PyUnicodeDecodeError\_GetEnd** (PyObject \*exc, Py\_ssize\_t \*end)

int **PyUnicodeEncodeError\_GetEnd** (PyObject \*exc, Py\_ssize\_t \*end)

int **PyUnicodeTranslateError\_GetEnd** (PyObject \*exc, Py\_ssize\_t \*end)

Get the *end* attribute of the given exception object and place it into \*end. *end* must not be *NULL*. Return 0 on success, -1 on failure.

int **PyUnicodeDecodeError\_SetEnd** (PyObject \*exc, Py\_ssize\_t end)

int **PyUnicodeEncodeError\_SetEnd** (PyObject \*exc, Py\_ssize\_t end)

int **PyUnicodeTranslateError\_SetEnd** (PyObject \*exc, Py\_ssize\_t end)

Set the *end* attribute of the given exception object to *end*. Return 0 on success, -1 on failure.

PyObject\* **PyUnicodeDecodeError\_GetReason** (PyObject \*exc)

PyObject\* **PyUnicodeEncodeError\_GetReason** (PyObject \*exc)

PyObject\* **PyUnicodeTranslateError\_GetReason** (PyObject \*exc)

Return the *reason* attribute of the given exception object.

int **PyUnicodeDecodeError\_SetReason** (PyObject \*exc, const char \*reason)

int **PyUnicodeEncodeError\_SetReason** (PyObject \*exc, const char \*reason)

int **PyUnicodeTranslateError\_SetReason** (PyObject \*exc, const char \*reason)

Set the *reason* attribute of the given exception object to *reason*. Return 0 on success, -1 on failure.

## 4.2 Recursion Control

These two functions provide a way to perform safe recursive calls at the C level, both in the core and in extension modules. They are needed if the recursive code does not necessarily invoke Python code (which tracks its recursion depth automatically).

int **Py\_EnterRecursiveCall** (char \*where)

Marks a point where a recursive C-level call is about to be performed.

If `USE_STACKCHECK` is defined, this function checks if the OS stack overflowed using `PyOS_CheckStack()`. In this is the case, it sets a `MemoryError` and returns a nonzero value.

The function then checks if the recursion limit is reached. If this is the case, a `RuntimeError` is set and a nonzero value is returned. Otherwise, zero is returned.

*where* should be a string such as " in instance check" to be concatenated to the `RuntimeError` message caused by the recursion depth limit.

void **Py\_LeaveRecursiveCall** ()

Ends a `Py_EnterRecursiveCall()`. Must be called once for each *successful* invocation of `Py_EnterRecursiveCall()`.

## 4.3 Standard Exceptions

All standard Python exceptions are available as global variables whose names are `PyExc_` followed by the Python exception name. These have the type `PyObject*`; they are all class objects. For completeness, here are all the variables:

C Name	Python Name	Notes
PyExc_BaseException	BaseException	(1), (4)
PyExc_Exception	Exception	(1)
PyExc_StandardError	StandardError	(1)
PyExc_ArithmeticError	ArithmeticError	(1)
PyExc_LookupError	LookupError	(1)
PyExc_AssertionError	AssertionError	
PyExc_AttributeError	AttributeError	
PyExc_EOFError	EOFError	
PyExc_EnvironmentError	EnvironmentError	(1)
PyExc_FloatingPointError	FloatingPointError	
PyExc_IOError	IOError	
PyExc_ImportError	ImportError	
PyExc_IndexError	IndexError	
PyExc_KeyError	KeyError	
PyExc_KeyboardInterrupt	KeyboardInterrupt	
PyExc_MemoryError	MemoryError	
PyExc_NameError	NameError	
PyExc_NotImplementedError	NotImplementedError	
PyExc_OSError	OSError	
PyExc_OverflowError	OverflowError	
PyExc_ReferenceError	ReferenceError	(2)
PyExc_RuntimeError	RuntimeError	
PyExc_SyntaxError	SyntaxError	
PyExc_SystemError	SystemError	
PyExc_SystemExit	SystemExit	
PyExc_TypeError	TypeError	
PyExc_ValueError	ValueError	
PyExc_WindowsError	WindowsError	(3)
PyExc_ZeroDivisionError	ZeroDivisionError	

Notes:

1. This is a base class for other standard exceptions.
2. This is the same as `weakref.ReferenceError`.
3. Only defined on Windows; protect code that uses this by testing that the preprocessor macro `MS_WINDOWS` is defined.
4. New in version 2.5.

## 4.4 String Exceptions

Changed in version 2.6: All exceptions to be raised or caught must be derived from `BaseException`. Trying to raise a string exception now raises `TypeError`.



# UTILITIES

The functions in this chapter perform various utility tasks, ranging from helping C code be more portable across platforms, using Python modules from C, and parsing function arguments and constructing Python values from C values.

## 5.1 Operating System Utilities

int **Py\_FdIsInteractive** (FILE \**fp*, const char \**filename*)

Return true (nonzero) if the standard I/O file *fp* with name *filename* is deemed interactive. This is the case for files for which `isatty(fileno(fp))` is true. If the global flag `Py_InteractiveFlag` is true, this function also returns true if the *filename* pointer is `NULL` or if the name is equal to one of the strings '`<stdin>`' or '`???`'.

void **PyOS\_AfterFork** ()

Function to update some internal state after a process fork; this should be called in the new process if the Python interpreter will continue to be used. If a new executable is loaded into the new process, this function does not need to be called.

int **PyOS\_CheckStack** ()

Return true when the interpreter runs out of stack space. This is a reliable check, but is only available when `USE_STACKCHECK` is defined (currently on Windows using the Microsoft Visual C++ compiler). `USE_STACKCHECK` will be defined automatically; you should never change the definition in your own code.

PyOS\_sighandler\_t **PyOS\_getsig** (int *i*)

Return the current signal handler for signal *i*. This is a thin wrapper around either `sigaction()` or `signal()`. Do not call those functions directly! `PyOS_sighandler_t` is a typedef alias for `void (*) (int)`.

PyOS\_sighandler\_t **PyOS\_setsig** (int *i*, PyOS\_sighandler\_t *h*)

Set the signal handler for signal *i* to be *h*; return the old signal handler. This is a thin wrapper around either `sigaction()` or `signal()`. Do not call those functions directly! `PyOS_sighandler_t` is a typedef alias for `void (*) (int)`.

## 5.2 System Functions

These are utility functions that make functionality from the `sys` module accessible to C code. They all work with the current interpreter thread's `sys` module's dict, which is contained in the internal thread state structure.

**PyObject \*PySys\_GetObject** (char \*name)

Return value: Borrowed reference.

Return the object *name* from the `sys` module or `NULL` if it does not exist, without setting an exception.

**FILE \*PySys\_GetFile** (char \*name, FILE \*def)

Return the `FILE*` associated with the object *name* in the `sys` module, or *def* if *name* is not in the module or is not associated with a `FILE*`.

**int PySys\_SetObject** (char \*name, PyObject \*v)

Set *name* in the `sys` module to *v* unless *v* is `NULL`, in which case *name* is deleted from the `sys` module. Returns 0 on success, -1 on error.

**void PySys\_ResetWarnOptions** ()

Reset `sys.warnoptions` to an empty list.

**void PySys\_AddWarnOption** (char \*s)

Append *s* to `sys.warnoptions`.

**void PySys\_SetPath** (char \*path)

Set `sys.path` to a list object of paths found in *path* which should be a list of paths separated with the platform's search path delimiter (: on Unix, ; on Windows).

**void PySys\_WriteStdout** (const char \*format, ...)

Write the output string described by *format* to `sys.stdout`. No exceptions are raised, even if truncation occurs (see below).

*format* should limit the total size of the formatted output string to 1000 bytes or less – after 1000 bytes, the output string is truncated. In particular, this means that no unrestricted “%s” formats should occur; these should be limited using “%.<N>s” where <N> is a decimal number calculated so that <N> plus the maximum size of other formatted text does not exceed 1000 bytes. Also watch out for “%f”, which can print hundreds of digits for very large numbers.

If a problem occurs, or `sys.stdout` is unset, the formatted message is written to the real (C level) *stdout*.

**void PySys\_WriteStderr** (const char \*format, ...)

As above, but write to `sys.stderr` or *stderr* instead.

## 5.3 Process Control

**void Py\_FatalError** (const char \*message)

Print a fatal error message and kill the process. No cleanup is performed. This function should only be invoked when a condition is detected that would make it dangerous to continue using the Python interpreter; e.g., when the object administration appears to be corrupted. On Unix, the standard C library function `abort()` is called which will attempt to produce a `core` file.

**void Py\_Exit** (int status)

Exit the current process. This calls `Py_Finalize()` and then calls the standard C library function `exit(status)`.

**int Py\_AtExit** (void (\*func)())

Register a cleanup function to be called by `Py_Finalize()`. The cleanup function will be called with no arguments and should return no value. At most 32 cleanup functions can be registered. When the registration is successful, `Py_AtExit()` returns 0; on failure, it returns -1. The cleanup function registered last is called first. Each cleanup function will be called at most once. Since Python's internal finalization will have completed before the cleanup function, no Python APIs should be called by *func*.

## 5.4 Importing Modules

**PyObject\*** **PyImport\_ImportModule** (const char \*name)

*Return value:* New reference.

This is a simplified interface to `PyImport_ImportModuleEx()` below, leaving the *globals* and *locals* arguments set to `NULL` and *level* set to 0. When the *name* argument contains a dot (when it specifies a submodule of a package), the *fromlist* argument is set to the list `['*']` so that the return value is the named module rather than the top-level package containing it as would otherwise be the case. (Unfortunately, this has an additional side effect when *name* in fact specifies a subpackage instead of a submodule: the submodules specified in the package's `__all__` variable are loaded.) Return a new reference to the imported module, or `NULL` with an exception set on failure. Before Python 2.4, the module may still be created in the failure case — examine `sys.modules` to find out. Starting with Python 2.4, a failing import of a module no longer leaves the module in `sys.modules`. Changed in version 2.4: Failing imports remove incomplete module objects. Changed in version 2.6: Always uses absolute imports.

**PyObject\*** **PyImport\_ImportModuleNoBlock** (const char \*name)

This version of `PyImport_ImportModule()` does not block. It's intended to be used in C functions that import other modules to execute a function. The import may block if another thread holds the import lock. The function `PyImport_ImportModuleNoBlock()` never blocks. It first tries to fetch the module from `sys.modules` and falls back to `PyImport_ImportModule()` unless the lock is held, in which case the function will raise an `ImportError`. New in version 2.6.

**PyObject\*** **PyImport\_ImportModuleEx** (char \*name, PyObject \*globals, PyObject \*locals, PyObject \*fromlist)

*Return value:* New reference.

Import a module. This is best described by referring to the built-in Python function `__import__()`, as the standard `__import__()` function calls this function directly.

The return value is a new reference to the imported module or top-level package, or `NULL` with an exception set on failure (before Python 2.4, the module may still be created in this case). Like for `__import__()`, the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty *fromlist* was given. Changed in version 2.4: Failing imports remove incomplete module objects. Changed in version 2.6: The function is an alias for `PyImport_ImportModuleLevel()` with -1 as level, meaning relative import.

**PyObject\*** **PyImport\_ImportModuleLevel** (char \*name, PyObject \*globals, PyObject \*locals, PyObject \*fromlist, int level)

*Return value:* New reference.

Import a module. This is best described by referring to the built-in Python function `__import__()`, as the standard `__import__()` function calls this function directly.

The return value is a new reference to the imported module or top-level package, or `NULL` with an exception set on failure. Like for `__import__()`, the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty *fromlist* was given. New in version 2.5.

**PyObject\*** **PyImport\_Import** (PyObject \*name)

*Return value:* New reference.

This is a higher-level interface that calls the current “import hook function”. It invokes the `__import__()` function from the `__builtins__` of the current globals. This means that the import is done using whatever import hooks are installed in the current environment, e.g. by `rexec` or `ihooks`. Changed in version 2.6: Always uses absolute imports.

**PyObject\*** **PyImport\_ReloadModule** (PyObject \*m)

*Return value:* New reference.

Reload a module. This is best described by referring to the built-in Python function `reload()`, as the standard `reload()` function calls this function directly. Return a new reference to the reloaded module, or `NULL` with an exception set on failure (the module still exists in this case).

**PyObject\*** **PyImport\_AddModule** (const char \*name)

*Return value:* Borrowed reference.

Return the module object corresponding to a module name. The *name* argument may be of the form `package.module`. First check the modules dictionary if there's one there, and if not, create a new one and insert it in the modules dictionary. Return *NULL* with an exception set on failure.

---

**Note:** This function does not load or import the module; if the module wasn't already loaded, you will get an empty module object. Use `PyImport_ImportModule()` or one of its variants to import a module. Package structures implied by a dotted name for *name* are not created if not already present.

---

**PyObject\*** **PyImport\_ExecCodeModule** (char \*name, PyObject \*co)

*Return value:* New reference.

Given a module name (possibly of the form `package.module`) and a code object read from a Python bytecode file or obtained from the built-in function `compile()`, load the module. Return a new reference to the module object, or *NULL* with an exception set if an error occurred. Before Python 2.4, the module could still be created in error cases. Starting with Python 2.4, *name* is removed from `sys.modules` in error cases, and even if *name* was already in `sys.modules` on entry to `PyImport_ExecCodeModule()`. Leaving incompletely initialized modules in `sys.modules` is dangerous, as imports of such modules have no way to know that the module object is an unknown (and probably damaged with respect to the module author's intents) state.

The module's `__file__` attribute will be set to the code object's `co_filename`.

This function will reload the module if it was already imported. See `PyImport_ReloadModule()` for the intended way to reload a module.

If *name* points to a dotted name of the form `package.module`, any package structures not already created will still not be created. Changed in version 2.4: *name* is removed from `sys.modules` in error cases.

**PyObject\*** **PyImport\_ExecCodeModuleEx** (char \*name, PyObject \*co, char \*pathname)

*Return value:* New reference.

Like `PyImport_ExecCodeModule()`, but the `__file__` attribute of the module object is set to *pathname* if it is non-*NULL*.

long **PyImport\_GetMagicNumber** ()

Return the magic number for Python bytecode files (a.k.a. `.pyc` and `.pyo` files). The magic number should be present in the first four bytes of the bytecode file, in little-endian byte order.

**PyObject\*** **PyImport\_GetModuleDict** ()

*Return value:* Borrowed reference.

Return the dictionary used for the module administration (a.k.a. `sys.modules`). Note that this is a per-interpreter variable.

**PyObject\*** **PyImport\_GetImporter** (PyObject \*path)

Return an importer object for a `sys.path/pkg.__path__` item *path*, possibly by fetching it from the `sys.path_importer_cache` dict. If it wasn't yet cached, traverse `sys.path_hooks` until a hook is found that can handle the path item. Return *None* if no hook could; this tells our caller it should fall back to the built-in import mechanism. Cache the result in `sys.path_importer_cache`. Return a new reference to the importer object. New in version 2.6.

void **\_PyImport\_Init** ()

Initialize the import mechanism. For internal use only.

void **PyImport\_Cleanup** ()

Empty the module table. For internal use only.

void **\_PyImport\_Fini** ()

Finalize the import mechanism. For internal use only.

`PyObject* PyImport_FindExtension (char *, char *)`  
For internal use only.

`PyObject* PyImport_FixupExtension (char *, char *)`  
For internal use only.

`int PyImport_ImportFrozenModule (char *name)`  
Load a frozen module named *name*. Return 1 for success, 0 if the module is not found, and -1 with an exception set if the initialization failed. To access the imported module on a successful load, use `PyImport_ImportModule()`. (Note the misnomer — this function would reload the module if it was already imported.)

`struct _frozen`  
This is the structure type definition for frozen module descriptors, as generated by the `freeze` utility (see `Tools/freeze/` in the Python source distribution). Its definition, found in `Include/import.h`, is:

```
struct _frozen {
    char *name;
    unsigned char *code;
    int size;
};
```

`struct _frozen* PyImport_FrozenModules`  
This pointer is initialized to point to an array of `struct _frozen` records, terminated by one whose members are all `NULL` or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.

`int PyImport_AppendInittab (const char *name, void (*initfunc)(void))`  
Add a single module to the existing table of built-in modules. This is a convenience wrapper around `PyImport_ExtendInittab()`, returning -1 if the table could not be extended. The new module can be imported by the name *name*, and uses the function *initfunc* as the initialization function called on the first attempted import. This should be called before `Py_Initialize()`.

`struct _inittab`  
Structure describing a single entry in the list of built-in modules. Each of these structures gives the name and initialization function for a module built into the interpreter. Programs which embed Python may use an array of these structures in conjunction with `PyImport_ExtendInittab()` to provide additional built-in modules. The structure is defined in `Include/import.h` as:

```
struct _inittab {
    char *name;
    void (*initfunc) (void);
};
```

`int PyImport_ExtendInittab (struct _inittab *newtab)`  
Add a collection of modules to the table of built-in modules. The *newtab* array must end with a sentinel entry which contains `NULL` for the *name* field; failure to provide the sentinel value can result in a memory fault. Returns 0 on success or -1 if insufficient memory could be allocated to extend the internal table. In the event of failure, no modules are added to the internal table. This should be called before `Py_Initialize()`.

## 5.5 Data marshalling support

These routines allow C code to work with serialized objects using the same data format as the `marshal` module. There are functions to write data into the serialization format, and additional functions that can be used to read the data back. Files used to store marshalled data must be opened in binary mode.

Numeric values are stored with the least significant byte first.

The module supports two versions of the data format: version 0 is the historical version, version 1 (new in Python 2.4) shares interned strings in the file, and upon unmarshalling. Version 2 (new in Python 2.5) uses a binary format for floating point numbers. `Py_MARSHAL_VERSION` indicates the current file format (currently 2).

void **PyMarshal\_WriteLongToFile** (long *value*, FILE *\*file*, int *version*)

Marshal a `long` integer, *value*, to *file*. This will only write the least-significant 32 bits of *value*; regardless of the size of the native `long` type. Changed in version 2.4: *version* indicates the file format.

void **PyMarshal\_WriteObjectToFile** (PyObject *\*value*, FILE *\*file*, int *version*)

Marshal a Python object, *value*, to *file*. Changed in version 2.4: *version* indicates the file format.

PyObject\* **PyMarshal\_WriteObjectToString** (PyObject *\*value*, int *version*)

*Return value:* *New reference.*

Return a string object containing the marshalled representation of *value*. Changed in version 2.4: *version* indicates the file format.

The following functions allow marshalled values to be read back in.

XXX What about error detection? It appears that reading past the end of the file will always result in a negative numeric value (where that's relevant), but it's not clear that negative values won't be handled properly when there's no error. What's the right way to tell? Should only non-negative values be written using these routines?

long **PyMarshal\_ReadLongFromFile** (FILE *\*file*)

Return a C `long` from the data stream in a `FILE*` opened for reading. Only a 32-bit value can be read in using this function, regardless of the native size of `long`.

int **PyMarshal\_ReadShortFromFile** (FILE *\*file*)

Return a C `short` from the data stream in a `FILE*` opened for reading. Only a 16-bit value can be read in using this function, regardless of the native size of `short`.

PyObject\* **PyMarshal\_ReadObjectFromFile** (FILE *\*file*)

*Return value:* *New reference.*

Return a Python object from the data stream in a `FILE*` opened for reading. On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns `NULL`.

PyObject\* **PyMarshal\_ReadLastObjectFromFile** (FILE *\*file*)

*Return value:* *New reference.*

Return a Python object from the data stream in a `FILE*` opened for reading. Unlike `PyMarshal_ReadObjectFromFile()`, this function assumes that no further objects will be read from the file, allowing it to aggressively load file data into memory so that the de-serialization can operate from data in memory rather than reading a byte at a time from the file. Only use these variant if you are certain that you won't be reading anything else from the file. On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns `NULL`.

PyObject\* **PyMarshal\_ReadObjectFromString** (char *\*string*, Py\_ssize\_t *len*)

*Return value:* *New reference.*

Return a Python object from the data stream in a character buffer containing *len* bytes pointed to by *string*. On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns `NULL`. Changed in version 2.5: This function used an `int` type for *len*. This might require changes in your code for properly supporting 64-bit systems.

## 5.6 Parsing arguments and building values

These functions are useful when creating your own extensions functions and methods. Additional information and examples are available in *extending-index*.

The first three of these functions described, `PyArg_ParseTuple()`, `PyArg_ParseTupleAndKeywords()`, and `PyArg_Parse()`, all use *format strings* which are used to tell the function about the expected arguments. The format strings use the same syntax for each of these functions.

A format string consists of zero or more “format units.” A format unit describes one Python object; it is usually a single character or a parenthesized sequence of format units. With a few exceptions, a format unit that is not a parenthesized sequence normally corresponds to a single address argument to these functions. In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that matches the format unit; and the entry in [square] brackets is the type of the C variable(s) whose address should be passed.

These formats allow to access an object as a contiguous chunk of memory. You don’t have to provide raw storage for the returned unicode or bytes area. Also, you won’t have to release any memory yourself, except with the `es`, `es#`, `et` and `et#` formats.

**s (string or Unicode) [const char \*]** Convert a Python string or Unicode object to a C pointer to a character string. You must not provide storage for the string itself; a pointer to an existing string is stored into the character pointer variable whose address you pass. The C string is NUL-terminated. The Python string must not contain embedded NUL bytes; if it does, a `TypeError` exception is raised. Unicode objects are converted to C strings using the default encoding. If this conversion fails, a `UnicodeError` is raised.

**s# (string, Unicode or any read buffer compatible object) [const char \*, int (or Py\_ssize\_t, see below)]**

This variant on `s` stores into two C variables, the first one a pointer to a character string, the second one its length. In this case the Python string may contain embedded null bytes. Unicode objects pass back a pointer to the default encoded string version of the object if such a conversion is possible. All other read-buffer compatible objects pass back a reference to the raw internal data representation.

Starting with Python 2.5 the type of the length argument can be controlled by defining the macro `PY_SSIZE_T_CLEAN` before including `Python.h`. If the macro is defined, `length` is a `Py_ssize_t` rather than an `int`.

**s\* (string, Unicode, or any buffer compatible object) [Py\_buffer]** Similar to `s#`, this code fills a `Py_buffer` structure provided by the caller. The buffer gets locked, so that the caller can subsequently use the buffer even inside a `Py_BEGIN_ALLOW_THREADS` block; the caller is responsible for calling `PyBuffer_Release` with the structure after it has processed the data. New in version 2.6.

**z (string, Unicode or None) [const char \*]** Like `s`, but the Python object may also be `None`, in which case the C pointer is set to `NULL`.

**z# (string, Unicode, None or any read buffer compatible object) [const char \*, int]** This is to `s#` as `z` is to `s`.

**z\* (string, Unicode, None or any buffer compatible object) [Py\_buffer]** This is to `s*` as `z` is to `s`. New in version 2.6.

**u (Unicode) [Py\_UNICODE \*]** Convert a Python Unicode object to a C pointer to a NUL-terminated buffer of 16-bit Unicode (UTF-16) data. As with `s`, there is no need to provide storage for the Unicode data buffer; a pointer to the existing Unicode data is stored into the `Py_UNICODE` pointer variable whose address you pass.

**u# (Unicode) [Py\_UNICODE \*, int]** This variant on `u` stores into two C variables, the first one a pointer to a Unicode data buffer, the second one its length. Non-Unicode objects are handled by interpreting their read-buffer pointer as pointer to a `Py_UNICODE` array.

**es (string, Unicode or character buffer compatible object) [const char \*encoding, char \*\*buffer]** This variant on `s` is used for encoding Unicode and objects convertible to Unicode into a character buffer. It only works for encoded data without embedded NUL bytes.

This format requires two arguments. The first is only used as input, and must be a `const char*` which points to the name of an encoding as a NUL-terminated string, or `NULL`, in which case the default encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a `char**`; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument.

`PyArg_ParseTuple()` will allocate a buffer of the needed size, copy the encoded data into this buffer and adjust `*buffer` to reference the newly allocated storage. The caller is responsible for calling `PyMem_Free()` to free the allocated buffer after use.

**et** (string, Unicode or character buffer compatible object) [`const char *encoding, char **buffer`] Same as `es` except that 8-bit string objects are passed through without recoding them. Instead, the implementation assumes that the string object uses the encoding passed in as parameter.

**es#** (string, Unicode or character buffer compatible object) [`const char *encoding, char **buffer, int *buffer_length`] This variant on `s#` is used for encoding Unicode and objects convertible to Unicode into a character buffer. Unlike the `es` format, this variant allows input data which contains NUL characters.

It requires three arguments. The first is only used as input, and must be a `const char*` which points to the name of an encoding as a NUL-terminated string, or `NULL`, in which case the default encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a `char**`; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument. The third argument must be a pointer to an integer; the referenced integer will be set to the number of bytes in the output buffer.

There are two modes of operation:

If `*buffer` points a `NULL` pointer, the function will allocate a buffer of the needed size, copy the encoded data into this buffer and set `*buffer` to reference the newly allocated storage. The caller is responsible for calling `PyMem_Free()` to free the allocated buffer after usage.

If `*buffer` points to a non-`NULL` pointer (an already allocated buffer), `PyArg_ParseTuple()` will use this location as the buffer and interpret the initial value of `*buffer_length` as the buffer size. It will then copy the encoded data into the buffer and NUL-terminate it. If the buffer is not large enough, a `ValueError` will be set.

In both cases, `*buffer_length` is set to the length of the encoded data without the trailing NUL byte.

**et#** (string, Unicode or character buffer compatible object) [`const char *encoding, char **buffer, int *buffer_length`] Same as `es#` except that string objects are passed through without recoding them. Instead, the implementation assumes that the string object uses the encoding passed in as parameter.

**b** (integer) [`unsigned char`] Convert a nonnegative Python integer to an unsigned tiny int, stored in a C `unsigned char`.

**B** (integer) [`unsigned char`] Convert a Python integer to a tiny int without overflow checking, stored in a C `unsigned char`. New in version 2.3.

**h** (integer) [`short int`] Convert a Python integer to a C `short int`.

**H** (integer) [`unsigned short int`] Convert a Python integer to a C `unsigned short int`, without overflow checking. New in version 2.3.

**i** (integer) [`int`] Convert a Python integer to a plain C `int`.

**I** (integer) [`unsigned int`] Convert a Python integer to a C `unsigned int`, without overflow checking. New in version 2.3.

**l** (integer) [`long int`] Convert a Python integer to a C `long int`.

**k** (integer) [`unsigned long`] Convert a Python integer or long integer to a C `unsigned long` without overflow checking. New in version 2.3.

**L** (integer) [`PY_LONG_LONG`] Convert a Python integer to a C `long long`. This format is only available on platforms that support `long long` (or `_int64` on Windows).

**K** (integer) [`unsigned PY_LONG_LONG`] Convert a Python integer or long integer to a C `unsigned long long` without overflow checking. This format is only available on platforms that support `unsigned long long` (or `unsigned _int64` on Windows). New in version 2.3.

- n (integer) [Py\_ssize\_t]** Convert a Python integer or long integer to a C `Py_ssize_t`. New in version 2.5.
- c (string of length 1) [char]** Convert a Python character, represented as a string of length 1, to a C `char`.
- f (float) [float]** Convert a Python floating point number to a C `float`.
- d (float) [double]** Convert a Python floating point number to a C `double`.
- D (complex) [Py\_complex]** Convert a Python complex number to a C `Py_complex` structure.
- O (object) [PyObject\*]** Store a Python object (without any conversion) in a C object pointer. The C program thus receives the actual object that was passed. The object's reference count is not increased. The pointer stored is not `NULL`.
- O! (object) [typeobject, PyObject\*]** Store a Python object in a C object pointer. This is similar to `O`, but takes two C arguments: the first is the address of a Python type object, the second is the address of the C variable (of type `PyObject*`) into which the object pointer is stored. If the Python object does not have the required type, `TypeError` is raised.
- O& (object) [converter, anything]** Convert a Python object to a C variable through a *converter* function. This takes two arguments: the first is a function, the second is the address of a C variable (of arbitrary type), converted to `void*`. The *converter* function in turn is called as follows:
- ```
status = converter(object, address);
```
- where *object* is the Python object to be converted and *address* is the `void*` argument that was passed to the `PyArg_Parse*()` function. The returned *status* should be 1 for a successful conversion and 0 if the conversion has failed. When the conversion fails, the *converter* function should raise an exception and leave the content of *address* unmodified.
- S (string) [PyStringObject\*]** Like `O` but requires that the Python object is a string object. Raises `TypeError` if the object is not a string object. The C variable may also be declared as `PyObject*`.
- U (Unicode string) [PyUnicodeObject\*]** Like `O` but requires that the Python object is a Unicode object. Raises `TypeError` if the object is not a Unicode object. The C variable may also be declared as `PyObject*`.
- t# (read-only character buffer) [char\*, int]** Like `s#`, but accepts any object which implements the read-only buffer interface. The `char*` variable is set to point to the first byte of the buffer, and the `int` is set to the length of the buffer. Only single-segment buffer objects are accepted; `TypeError` is raised for all others.
- w (read-write character buffer) [char\*]** Similar to `s`, but accepts any object which implements the read-write buffer interface. The caller must determine the length of the buffer by other means, or use `w#` instead. Only single-segment buffer objects are accepted; `TypeError` is raised for all others.
- w# (read-write character buffer) [char\*, Py\_ssize\_t]** Like `s#`, but accepts any object which implements the read-write buffer interface. The `char*` variable is set to point to the first byte of the buffer, and the `Py_ssize_t` is set to the length of the buffer. Only single-segment buffer objects are accepted; `TypeError` is raised for all others.
- w\* (read-write byte-oriented buffer) [Py\_buffer]** This is to `w` what `s*` is to `s`. New in version 2.6.
- (items) (tuple) [matching-items]** The object must be a Python sequence whose length is the number of format units in *items*. The C arguments must correspond to the individual format units in *items*. Format units for sequences may be nested.

---

**Note:** Prior to Python version 1.5.2, this format specifier only accepted a tuple containing the individual parameters, not an arbitrary sequence. Code which previously caused `TypeError` to be raised here may now proceed without an exception. This is not expected to be a problem for existing code.

---

It is possible to pass Python long integers where integers are requested; however no proper range checking is done — the most significant bits are silently truncated when the receiving field is too small to receive the value (actually, the semantics are inherited from downcasts in C — your mileage may vary).

A few other characters have a meaning in a format string. These may not occur inside nested parentheses. They are:

- | Indicates that the remaining arguments in the Python argument list are optional. The C variables corresponding to optional arguments should be initialized to their default value — when an optional argument is not specified, `PyArg_ParseTuple()` does not touch the contents of the corresponding C variable(s).
- : The list of format units ends here; the string after the colon is used as the function name in error messages (the “associated value” of the exception that `PyArg_ParseTuple()` raises).
- ; The list of format units ends here; the string after the semicolon is used as the error message *instead* of the default error message. `:` and `;` mutually exclude each other.

Note that any Python object references which are provided to the caller are *borrowed* references; do not decrement their reference count!

Additional arguments passed to these functions must be addresses of variables whose type is determined by the format string; these are used to store values from the input tuple. There are a few cases, as described in the list of format units above, where these parameters are used as input values; they should match what is specified for the corresponding format unit in that case.

For the conversion to succeed, the *arg* object must match the format and the format must be exhausted. On success, the `PyArg_Parse*` functions return true, otherwise they return false and raise an appropriate exception. When the `PyArg_Parse*` functions fail due to conversion failure in one of the format units, the variables at the addresses corresponding to that and the following format units are left untouched.

int `PyArg_ParseTuple` (`PyObject` \*args, const char \*format, ...)

Parse the parameters of a function that takes only positional parameters into local variables. Returns true on success; on failure, it returns false and raises the appropriate exception.

int `PyArg_VaParse` (`PyObject` \*args, const char \*format, va\_list vargs)

Identical to `PyArg_ParseTuple()`, except that it accepts a `va_list` rather than a variable number of arguments.

int `PyArg_ParseTupleAndKeywords` (`PyObject` \*args, `PyObject` \*kw, const char \*format, char \*keywords[], ...)

Parse the parameters of a function that takes both positional and keyword parameters into local variables. Returns true on success; on failure, it returns false and raises the appropriate exception.

int `PyArg_VaParseTupleAndKeywords` (`PyObject` \*args, `PyObject` \*kw, const char \*format, char \*keywords[], va\_list vargs)

Identical to `PyArg_ParseTupleAndKeywords()`, except that it accepts a `va_list` rather than a variable number of arguments.

int `PyArg_Parse` (`PyObject` \*args, const char \*format, ...)

Function used to deconstruct the argument lists of “old-style” functions — these are functions which use the `METH_OLDARGS` parameter parsing method. This is not recommended for use in parameter parsing in new code, and most code in the standard interpreter has been modified to no longer use this for that purpose. It does remain a convenient way to decompose other tuples, however, and may continue to be used for that purpose.

int `PyArg_UnpackTuple` (`PyObject` \*args, const char \*name, `Py_ssize_t` min, `Py_ssize_t` max, ...)

A simpler form of parameter retrieval which does not use a format string to specify the types of the arguments. Functions which use this method to retrieve their parameters should be declared as `METH_VARARGS` in function or method tables. The tuple containing the actual parameters should be passed as *args*; it must actually be a tuple. The length of the tuple must be at least *min* and no more than *max*; *min* and *max* may be equal. Additional arguments must be passed to the function, each of which should be a pointer to a `PyObject*` variable; these will be filled in with the values from *args*; they will contain borrowed references. The variables which correspond to optional parameters not given by *args* will not be filled in; these should be initialized by

the caller. This function returns true on success and false if *args* is not a tuple or contains the wrong number of elements; an exception will be set if there was a failure.

This is an example of the use of this function, taken from the sources for the `_weakref` helper module for weak references:

```
static PyObject *
weakref_ref(PyObject *self, PyObject *args)
{
    PyObject *object;
    PyObject *callback = NULL;
    PyObject *result = NULL;

    if (PyArg_UnpackTuple(args, "ref", 1, 2, &object, &callback)) {
        result = PyWeakref_NewRef(object, callback);
    }
    return result;
}
```

The call to `PyArg_UnpackTuple()` in this example is entirely equivalent to this call to `PyArg_ParseTuple()`:

```
PyArg_ParseTuple(args, "O|O:ref", &object, &callback)
```

New in version 2.2.Changed in version 2.5: This function used an `int` type for *min* and *max*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** `Py_BuildValue` (const char \**format*, ...)

*Return value:* New reference.

Create a new value based on a format string similar to those accepted by the `PyArg_Parse*()` family of functions and a sequence of values. Returns the value or `NULL` in the case of an error; an exception will be raised if `NULL` is returned.

`Py_BuildValue()` does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns `None`; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

When memory buffers are passed as parameters to supply data to build objects, as for the `s` and `s#` formats, the required data is copied. Buffers provided by the caller are never referenced by the objects created by `Py_BuildValue()`. In other words, if your code invokes `malloc()` and passes the allocated memory to `Py_BuildValue()`, your code is responsible for calling `free()` for that memory once `Py_BuildValue()` returns.

In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that the format unit will return; and the entry in [square] brackets is the type of the C value(s) to be passed.

The characters space, tab, colon and comma are ignored in format strings (but not within format units such as `s#`). This can be used to make long format strings a tad more readable.

**s (string) [char \*]** Convert a null-terminated C string to a Python object. If the C string pointer is `NULL`, `None` is used.

**s# (string) [char \*, int]** Convert a C string and its length to a Python object. If the C string pointer is `NULL`, the length is ignored and `None` is returned.

**z (string or None) [char \*]** Same as `s`.

- z# (string or None) [char \*, int]** Same as `s#`.
- u (Unicode string) [Py\_UNICODE \*]** Convert a null-terminated buffer of Unicode (UCS-2 or UCS-4) data to a Python Unicode object. If the Unicode buffer pointer is `NULL`, `None` is returned.
- u# (Unicode string) [Py\_UNICODE \*, int]** Convert a Unicode (UCS-2 or UCS-4) data buffer and its length to a Python Unicode object. If the Unicode buffer pointer is `NULL`, the length is ignored and `None` is returned.
- i (integer) [int]** Convert a plain C `int` to a Python integer object.
- b (integer) [char]** Convert a plain C `char` to a Python integer object.
- h (integer) [short int]** Convert a plain C `short int` to a Python integer object.
- l (integer) [long int]** Convert a C `long int` to a Python integer object.
- B (integer) [unsigned char]** Convert a C `unsigned char` to a Python integer object.
- H (integer) [unsigned short int]** Convert a C `unsigned short int` to a Python integer object.
- I (integer/long) [unsigned int]** Convert a C `unsigned int` to a Python integer object or a Python long integer object, if it is larger than `sys.maxint`.
- k (integer/long) [unsigned long]** Convert a C `unsigned long` to a Python integer object or a Python long integer object, if it is larger than `sys.maxint`.
- L (long) [PY\_LONG\_LONG]** Convert a C `long long` to a Python long integer object. Only available on platforms that support `long long`.
- K (long) [unsigned PY\_LONG\_LONG]** Convert a C `unsigned long long` to a Python long integer object. Only available on platforms that support `unsigned long long`.
- n (int) [Py\_ssize\_t]** Convert a C `Py_ssize_t` to a Python integer or long integer. New in version 2.5.
- c (string of length 1) [char]** Convert a C `int` representing a character to a Python string of length 1.
- d (float) [double]** Convert a C `double` to a Python floating point number.
- f (float) [float]** Same as `d`.
- D (complex) [Py\_complex \*]** Convert a C `Py_complex` structure to a Python complex number.
- O (object) [PyObject \*]** Pass a Python object untouched (except for its reference count, which is incremented by one). If the object passed in is a `NULL` pointer, it is assumed that this was caused because the call producing the argument found an error and set an exception. Therefore, `Py_BuildValue()` will return `NULL` but won't raise an exception. If no exception has been raised yet, `SystemError` is set.
- S (object) [PyObject \*]** Same as `O`.
- N (object) [PyObject \*]** Same as `O`, except it doesn't increment the reference count on the object. Useful when the object is created by a call to an object constructor in the argument list.
- O& (object) [converter, anything]** Convert *anything* to a Python object through a *converter* function. The function is called with *anything* (which should be compatible with `void *`) as its argument and should return a "new" Python object, or `NULL` if an error occurred.
- (items) (tuple) [matching-items]** Convert a sequence of C values to a Python tuple with the same number of items.
- [items] (list) [matching-items]** Convert a sequence of C values to a Python list with the same number of items.
- {items} (dictionary) [matching-items]** Convert a sequence of C values to a Python dictionary. Each pair of consecutive C values adds one item to the dictionary, serving as key and value, respectively.

If there is an error in the format string, the `SystemError` exception is set and `NULL` returned.

`PyObject* Py_VaBuildValue` (const char \*format, va\_list vars)

Identical to `Py_BuildValue()`, except that it accepts a `va_list` rather than a variable number of arguments.

## 5.7 String conversion and formatting

Functions for number conversion and formatted string output.

int `PyOS_snprintf` (char \*str, size\_t size, const char \*format, ...)

Output not more than `size` bytes to `str` according to the format string `format` and the extra arguments. See the Unix man page `snprintf(2)`.

int `PyOS_vsnprintf` (char \*str, size\_t size, const char \*format, va\_list va)

Output not more than `size` bytes to `str` according to the format string `format` and the variable argument list `va`. Unix man page `vsnprintf(2)`.

`PyOS_snprintf()` and `PyOS_vsnprintf()` wrap the Standard C library functions `snprintf()` and `vsnprintf()`. Their purpose is to guarantee consistent behavior in corner cases, which the Standard C functions do not.

The wrappers ensure that `str[*size-1]` is always `'\0'` upon return. They never write more than `size` bytes (including the trailing `'\0'` into `str`. Both functions require that `str != NULL`, `size > 0` and `format != NULL`.

If the platform doesn't have `vsnprintf()` and the buffer size needed to avoid truncation exceeds `size` by more than 512 bytes, Python aborts with a `Py_FatalError`.

The return value (`rv`) for these functions should be interpreted as follows:

- When  $0 \leq rv < size$ , the output conversion was successful and `rv` characters were written to `str` (excluding the trailing `'\0'` byte at `str[*rv]`).
- When  $rv \geq size$ , the output conversion was truncated and a buffer with `rv + 1` bytes would have been needed to succeed. `str[*size-1]` is `'\0'` in this case.
- When  $rv < 0$ , "something bad happened." `str[*size-1]` is `'\0'` in this case too, but the rest of `str` is undefined. The exact cause of the error depends on the underlying platform.

The following functions provide locale-independent string to number conversions.

double `PyOS_string_to_double` (const char \*s, char \*\*endptr, PyObject \*overflow\_exception)

Convert a string `s` to a `double`, raising a Python exception on failure. The set of accepted strings corresponds to the set of strings accepted by Python's `float()` constructor, except that `s` must not have leading or trailing whitespace. The conversion is independent of the current locale.

If `endptr` is `NULL`, convert the whole string. Raise `ValueError` and return `-1.0` if the string is not a valid representation of a floating-point number.

If `endptr` is not `NULL`, convert as much of the string as possible and set `*endptr` to point to the first unconverted character. If no initial segment of the string is the valid representation of a floating-point number, set `*endptr` to point to the beginning of the string, raise `ValueError`, and return `-1.0`.

If `s` represents a value that is too large to store in a float (for example, `"1e500"` is such a string on many platforms) then if `overflow_exception` is `NULL` return `Py_HUGE_VAL` (with an appropriate sign) and don't set any exception. Otherwise, `overflow_exception` must point to a Python exception object; raise that exception and return `-1.0`. In both cases, set `*endptr` to point to the first character after the converted value.

If any other error occurs during the conversion (for example an out-of-memory error), set the appropriate Python exception and return `-1.0`. New in version 2.7.

double **PyOS\_ascii\_strtod**(const char \*nptr, char \*\*endptr)

Convert a string to a double. This function behaves like the Standard C function `strtod()` does in the C locale. It does this without changing the current locale, since that would not be thread-safe.

`PyOS_ascii_strtod()` should typically be used for reading configuration files or other non-user input that should be locale independent.

See the Unix man page `strtod(2)` for details. New in version 2.4. Deprecated since version 2.7: Use `PyOS_string_to_double()` instead.

char\* **PyOS\_ascii\_formatd**(char \*buffer, size\_t buf\_len, const char \*format, double d)

Convert a double to a string using the '.' as the decimal separator. *format* is a `printf()`-style format string specifying the number format. Allowed conversion characters are 'e', 'E', 'f', 'F', 'g' and 'G'.

The return value is a pointer to *buffer* with the converted string or NULL if the conversion failed. New in version 2.4. Deprecated since version 2.7: This function is removed in Python 2.7 and 3.1. Use `PyOS_double_to_string()` instead.

char\* **PyOS\_double\_to\_string**(double val, char format\_code, int precision, int flags, int \*ptype)

Convert a double *val* to a string using supplied *format\_code*, *precision*, and *flags*.

*format\_code* must be one of 'e', 'E', 'f', 'F', 'g', 'G' or 'r'. For 'r', the supplied *precision* must be 0 and is ignored. The 'r' format code specifies the standard `repr()` format.

*flags* can be zero or more of the values `Py_DTST_SIGN`, `Py_DTST_ADD_DOT_0`, or `Py_DTST_ALT`, or-ed together:

- `Py_DTST_SIGN` means to always precede the returned string with a sign character, even if *val* is non-negative.
- `Py_DTST_ADD_DOT_0` means to ensure that the returned string will not look like an integer.
- `Py_DTST_ALT` means to apply “alternate” formatting rules. See the documentation for the `PyOS_snprintf()` '#' specifier for details.

If *ptype* is non-NULL, then the value it points to will be set to one of `Py_DTST_FINITE`, `Py_DTST_INFINITY`, or `Py_DTST_NAN`, signifying that *val* is a finite number, an infinite number, or not a number, respectively.

The return value is a pointer to *buffer* with the converted string or NULL if the conversion failed. The caller is responsible for freeing the returned string by calling `PyMem_Free()`. New in version 2.7.

double **PyOS\_ascii\_atof**(const char \*nptr)

Convert a string to a double in a locale-independent way.

See the Unix man page `atof(2)` for details. New in version 2.4. Deprecated since version 3.1: Use `PyOS_string_to_double()` instead.

char\* **PyOS\_stricmp**(char \*s1, char \*s2)

Case insensitive comparison of strings. The function works almost identically to `strcmp()` except that it ignores the case. New in version 2.6.

char\* **PyOS\_strnicmp**(char \*s1, char \*s2, Py\_ssize\_t size)

Case insensitive comparison of strings. The function works almost identically to `strncmp()` except that it ignores the case. New in version 2.6.

## 5.8 Reflection

PyObject\* **PyEval\_GetBuiltins**()

Return value: Borrowed reference.

Return a dictionary of the builtins in the current execution frame, or the interpreter of the thread state if no frame is currently executing.

**PyObject\*** **PyEval\_GetLocals** ()

*Return value: Borrowed reference.*

Return a dictionary of the local variables in the current execution frame, or *NULL* if no frame is currently executing.

**PyObject\*** **PyEval\_GetGlobals** ()

*Return value: Borrowed reference.*

Return a dictionary of the global variables in the current execution frame, or *NULL* if no frame is currently executing.

**PyFrameObject\*** **PyEval\_GetFrame** ()

*Return value: Borrowed reference.*

Return the current thread state's frame, which is *NULL* if no frame is currently executing.

**int** **PyFrame\_GetLineNumber** (PyFrameObject \**frame*)

Return the line number that *frame* is currently executing.

**int** **PyEval\_GetRestricted** ()

If there is a current frame and it is executing in restricted mode, return true, otherwise false.

**const char\*** **PyEval\_GetFuncName** (PyObject \**func*)

Return the name of *func* if it is a function, class or instance object, else the name of *func*'s type.

**const char\*** **PyEval\_GetFuncDesc** (PyObject \**func*)

Return a description string, depending on the type of *func*. Return values include “()” for functions and methods, ” constructor”, ” instance”, and ” object”. Concatenated with the result of `PyEval_GetFuncName()`, the result will be a description of *func*.

## 5.9 Codec registry and support functions

**int** **PyCodec\_Register** (PyObject \**search\_function*)

Register a new codec search function.

As side effect, this tries to load the `encodings` package, if not yet done, to make sure that it is always first in the list of search functions.

**int** **PyCodec\_KnownEncoding** (const char \**encoding*)

Return 1 or 0 depending on whether there is a registered codec for the given *encoding*.

**PyObject\*** **PyCodec\_Encode** (PyObject \**object*, const char \**encoding*, const char \**errors*)

Generic codec based encoding API.

*object* is passed through the encoder function found for the given *encoding* using the error handling method defined by *errors*. *errors* may be *NULL* to use the default method defined for the codec. Raises a `LookupError` if no encoder can be found.

**PyObject\*** **PyCodec\_Decode** (PyObject \**object*, const char \**encoding*, const char \**errors*)

Generic codec based decoding API.

*object* is passed through the decoder function found for the given *encoding* using the error handling method defined by *errors*. *errors* may be *NULL* to use the default method defined for the codec. Raises a `LookupError` if no decoder can be found.

## 5.9.1 Codec lookup API

In the following functions, the *encoding* string is looked up converted to all lower-case characters, which makes encodings looked up through this mechanism effectively case-insensitive. If no codec is found, a `KeyError` is set and `NULL` returned.

`PyObject*` **PyCodec\_Encoder** (const char \**encoding*)  
Get an encoder function for the given *encoding*.

`PyObject*` **PyCodec\_Decoder** (const char \**encoding*)  
Get a decoder function for the given *encoding*.

`PyObject*` **PyCodec\_IncrementalEncoder** (const char \**encoding*, const char \**errors*)  
Get an `IncrementalEncoder` object for the given *encoding*.

`PyObject*` **PyCodec\_IncrementalDecoder** (const char \**encoding*, const char \**errors*)  
Get an `IncrementalDecoder` object for the given *encoding*.

`PyObject*` **PyCodec\_StreamReader** (const char \**encoding*, `PyObject` \**stream*, const char \**errors*)  
Get a `StreamReader` factory function for the given *encoding*.

`PyObject*` **PyCodec\_StreamWriter** (const char \**encoding*, `PyObject` \**stream*, const char \**errors*)  
Get a `StreamWriter` factory function for the given *encoding*.

## 5.9.2 Registry API for Unicode encoding error handlers

`int` **PyCodec\_RegisterError** (const char \**name*, `PyObject` \**error*)

Register the error handling callback function *error* under the given *name*. This callback function will be called by a codec when it encounters unencodable characters/undecodable bytes and *name* is specified as the error parameter in the call to the encode/decode function.

The callback gets a single argument, an instance of `UnicodeEncodeError`, `UnicodeDecodeError` or `UnicodeTranslateError` that holds information about the problematic sequence of characters or bytes and their offset in the original string (see *Unicode Exception Objects* for functions to extract this information). The callback must either raise the given exception, or return a two-item tuple containing the replacement for the problematic sequence, and an integer giving the offset in the original string at which encoding/decoding should be resumed.

Return 0 on success, -1 on error.

`PyObject*` **PyCodec\_LookupError** (const char \**name*)

Lookup the error handling callback function registered under *name*. As a special case `NULL` can be passed, in which case the error handling callback for “strict” will be returned.

`PyObject*` **PyCodec\_StrictErrors** (`PyObject` \**exc*)  
Raise *exc* as an exception.

`PyObject*` **PyCodec\_IgnoreErrors** (`PyObject` \**exc*)  
Ignore the unicode error, skipping the faulty input.

`PyObject*` **PyCodec\_ReplaceErrors** (`PyObject` \**exc*)  
Replace the unicode encode error with ? or U+FFFD.

`PyObject*` **PyCodec\_XMLCharRefReplaceErrors** (`PyObject` \**exc*)  
Replace the unicode encode error with XML character references.

`PyObject*` **PyCodec\_BackslashReplaceErrors** (`PyObject` \**exc*)  
Replace the unicode encode error with backslash escapes (`\x`, `\u` and `\U`).

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# ABSTRACT OBJECTS LAYER

The functions in this chapter interact with Python objects regardless of their type, or with wide classes of object types (e.g. all numerical types, or all sequence types). When used on object types for which they do not apply, they will raise a Python exception.

It is not possible to use these functions on objects that are not properly initialized, such as a list object that has been created by `PyList_New()`, but whose items have not been set to some non-NULL value yet.

## 6.1 Object Protocol

`int PyObject_Print (PyObject *o, FILE *fp, int flags)`

Print an object *o*, on file *fp*. Returns `-1` on error. The flags argument is used to enable certain printing options. The only option currently supported is `Py_PRINT_RAW`; if given, the `str()` of the object is written instead of the `repr()`.

`int PyObject_HasAttr (PyObject *o, PyObject *attr_name)`

Returns `1` if *o* has the attribute *attr\_name*, and `0` otherwise. This is equivalent to the Python expression `hasattr(o, attr_name)`. This function always succeeds.

`int PyObject_HasAttrString (PyObject *o, const char *attr_name)`

Returns `1` if *o* has the attribute *attr\_name*, and `0` otherwise. This is equivalent to the Python expression `hasattr(o, attr_name)`. This function always succeeds.

`PyObject* PyObject_GetAttr (PyObject *o, PyObject *attr_name)`

*Return value:* New reference.

Retrieve an attribute named *attr\_name* from object *o*. Returns the attribute value on success, or `NULL` on failure. This is the equivalent of the Python expression `o.attr_name`.

`PyObject* PyObject_GetAttrString (PyObject *o, const char *attr_name)`

*Return value:* New reference.

Retrieve an attribute named *attr\_name* from object *o*. Returns the attribute value on success, or `NULL` on failure. This is the equivalent of the Python expression `o.attr_name`.

`PyObject* PyObject_GenericGetAttr (PyObject *o, PyObject *name)`

Generic attribute getter function that is meant to be put into a type object's `tp_getattro` slot. It looks for a descriptor in the dictionary of classes in the object's MRO as well as an attribute in the object's `__dict__` (if present). As outlined in *descriptors*, data descriptors take preference over instance attributes, while non-data descriptors don't. Otherwise, an `AttributeError` is raised.

`int PyObject_SetAttr (PyObject *o, PyObject *attr_name, PyObject *v)`

Set the value of the attribute named *attr\_name*, for object *o*, to the value *v*. Returns `-1` on failure. This is the equivalent of the Python statement `o.attr_name = v`.

int **PyObject\_SetAttrString** (PyObject \*o, const char \*attr\_name, PyObject \*v)

Set the value of the attribute named *attr\_name*, for object *o*, to the value *v*. Returns `-1` on failure. This is the equivalent of the Python statement `o.attr_name = v`.

int **PyObject\_GenericSetAttr** (PyObject \*o, PyObject \*name, PyObject \*value)

Generic attribute setter function that is meant to be put into a type object's `tp_setattro` slot. It looks for a data descriptor in the dictionary of classes in the object's MRO, and if found it takes preference over setting the attribute in the instance dictionary. Otherwise, the attribute is set in the object's `__dict__` (if present). Otherwise, an `AttributeError` is raised and `-1` is returned.

int **PyObject\_DelAttr** (PyObject \*o, PyObject \*attr\_name)

Delete attribute named *attr\_name*, for object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o.attr_name`.

int **PyObject\_DelAttrString** (PyObject \*o, const char \*attr\_name)

Delete attribute named *attr\_name*, for object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o.attr_name`.

PyObject\* **PyObject\_RichCompare** (PyObject \*o1, PyObject \*o2, int opid)

*Return value:* New reference.

Compare the values of *o1* and *o2* using the operation specified by *opid*, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to *opid*. Returns the value of the comparison on success, or `NULL` on failure.

int **PyObject\_RichCompareBool** (PyObject \*o1, PyObject \*o2, int opid)

Compare the values of *o1* and *o2* using the operation specified by *opid*, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. Returns `-1` on error, `0` if the result is false, `1` otherwise. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to *opid*.

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**Note:** If *o1* and *o2* are the same object, `PyObject_RichCompareBool()` will always return `1` for `Py_EQ` and `0` for `Py_NE`.

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int **PyObject\_Cmp** (PyObject \*o1, PyObject \*o2, int \*result)

Compare the values of *o1* and *o2* using a routine provided by *o1*, if one exists, otherwise with a routine provided by *o2*. The result of the comparison is returned in *result*. Returns `-1` on failure. This is the equivalent of the Python statement `result = cmp(o1, o2)`.

int **PyObject\_Compare** (PyObject \*o1, PyObject \*o2)

Compare the values of *o1* and *o2* using a routine provided by *o1*, if one exists, otherwise with a routine provided by *o2*. Returns the result of the comparison on success. On error, the value returned is undefined; use `PyErr_Occurred()` to detect an error. This is equivalent to the Python expression `cmp(o1, o2)`.

PyObject\* **PyObject\_Repr** (PyObject \*o)

*Return value:* New reference.

Compute a string representation of object *o*. Returns the string representation on success, `NULL` on failure. This is the equivalent of the Python expression `repr(o)`. Called by the `repr()` built-in function and by reverse quotes.

PyObject\* **PyObject\_Str** (PyObject \*o)

*Return value:* New reference.

Compute a string representation of object *o*. Returns the string representation on success, `NULL` on failure. This is the equivalent of the Python expression `str(o)`. Called by the `str()` built-in function and by the `print` statement.

PyObject\* **PyObject\_Bytes** (PyObject \*o)

Compute a bytes representation of object *o*. In 2.x, this is just a alias for `PyObject_Str()`.

**PyObject\*** **PyObject\_Unicode** (PyObject \*o)

*Return value:* New reference.

Compute a Unicode string representation of object *o*. Returns the Unicode string representation on success, *NULL* on failure. This is the equivalent of the Python expression `unicode(o)`. Called by the `unicode()` built-in function.

**int** **PyObject\_IsInstance** (PyObject \*inst, PyObject \*cls)

Returns 1 if *inst* is an instance of the class *cls* or a subclass of *cls*, or 0 if not. On error, returns -1 and sets an exception. If *cls* is a type object rather than a class object, `PyObject_IsInstance()` returns 1 if *inst* is of type *cls*. If *cls* is a tuple, the check will be done against every entry in *cls*. The result will be 1 when at least one of the checks returns 1, otherwise it will be 0. If *inst* is not a class instance and *cls* is neither a type object, nor a class object, nor a tuple, *inst* must have a `__class__` attribute — the class relationship of the value of that attribute with *cls* will be used to determine the result of this function. New in version 2.1. Changed in version 2.2: Support for a tuple as the second argument added.

Subclass determination is done in a fairly straightforward way, but includes a wrinkle that implementors of extensions to the class system may want to be aware of. If *A* and *B* are class objects, *B* is a subclass of *A* if it inherits from *A* either directly or indirectly. If either is not a class object, a more general mechanism is used to determine the class relationship of the two objects. When testing if *B* is a subclass of *A*, if *A* is *B*, `PyObject_IsSubclass()` returns true. If *A* and *B* are different objects, *B*'s `__bases__` attribute is searched in a depth-first fashion for *A* — the presence of the `__bases__` attribute is considered sufficient for this determination.

**int** **PyObject\_IsSubclass** (PyObject \*derived, PyObject \*cls)

Returns 1 if the class *derived* is identical to or derived from the class *cls*, otherwise returns 0. In case of an error, returns -1. If *cls* is a tuple, the check will be done against every entry in *cls*. The result will be 1 when at least one of the checks returns 1, otherwise it will be 0. If either *derived* or *cls* is not an actual class object (or tuple), this function uses the generic algorithm described above. New in version 2.1. Changed in version 2.3: Older versions of Python did not support a tuple as the second argument.

**int** **PyObject\_Check** (PyObject \*o)

Determine if the object *o* is callable. Return 1 if the object is callable and 0 otherwise. This function always succeeds.

**PyObject\*** **PyObject\_Call** (PyObject \*callable\_object, PyObject \*args, PyObject \*kw)

*Return value:* New reference.

Call a callable Python object *callable\_object*, with arguments given by the tuple *args*, and named arguments given by the dictionary *kw*. If no named arguments are needed, *kw* may be *NULL*. *args* must not be *NULL*, use an empty tuple if no arguments are needed. Returns the result of the call on success, or *NULL* on failure. This is the equivalent of the Python expression `apply(callable_object, args, kw)` or `callable_object(*args, **kw)`. New in version 2.2.

**PyObject\*** **PyObject\_CallObject** (PyObject \*callable\_object, PyObject \*args)

*Return value:* New reference.

Call a callable Python object *callable\_object*, with arguments given by the tuple *args*. If no arguments are needed, then *args* may be *NULL*. Returns the result of the call on success, or *NULL* on failure. This is the equivalent of the Python expression `apply(callable_object, args)` or `callable_object(*args)`.

**PyObject\*** **PyObject\_CallFunction** (PyObject \*callable, char \*format, ...)

*Return value:* New reference.

Call a callable Python object *callable*, with a variable number of C arguments. The C arguments are described using a `Py_BuildValue()` style format string. The format may be *NULL*, indicating that no arguments are provided. Returns the result of the call on success, or *NULL* on failure. This is the equivalent of the Python expression `apply(callable, args)` or `callable(*args)`. Note that if you only pass `PyObject *args`, `PyObject_CallFunctionObjArgs()` is a faster alternative.

**PyObject\*** **PyObject\_CallMethod** (PyObject \*o, char \*method, char \*format, ...)

*Return value:* New reference.

Call the method named *method* of object *o* with a variable number of C arguments. The C arguments are

described by a `Py_BuildValue()` format string that should produce a tuple. The format may be `NULL`, indicating that no arguments are provided. Returns the result of the call on success, or `NULL` on failure. This is the equivalent of the Python expression `o.method(args)`. Note that if you only pass `PyObject *args`, `PyObject_CallMethodObjArgs()` is a faster alternative.

**PyObject\* PyObject\_CallFunctionObjArgs** (PyObject \*callable, ..., NULL)

*Return value:* New reference.

Call a callable Python object *callable*, with a variable number of `PyObject*` arguments. The arguments are provided as a variable number of parameters followed by `NULL`. Returns the result of the call on success, or `NULL` on failure. New in version 2.2.

**PyObject\* PyObject\_CallMethodObjArgs** (PyObject \*o, PyObject \*name, ..., NULL)

*Return value:* New reference.

Calls a method of the object *o*, where the name of the method is given as a Python string object in *name*. It is called with a variable number of `PyObject*` arguments. The arguments are provided as a variable number of parameters followed by `NULL`. Returns the result of the call on success, or `NULL` on failure. New in version 2.2.

**long PyObject\_Hash** (PyObject \*o)

Compute and return the hash value of an object *o*. On failure, return `-1`. This is the equivalent of the Python expression `hash(o)`.

**long PyObject\_HashNotImplemented** (PyObject \*o)

Set a `TypeError` indicating that `type(o)` is not hashable and return `-1`. This function receives special treatment when stored in a `tp_hash` slot, allowing a type to explicitly indicate to the interpreter that it is not hashable. New in version 2.6.

**int PyObject\_IsTrue** (PyObject \*o)

Returns 1 if the object *o* is considered to be true, and 0 otherwise. This is equivalent to the Python expression `not not o`. On failure, return `-1`.

**int PyObject\_Not** (PyObject \*o)

Returns 0 if the object *o* is considered to be true, and 1 otherwise. This is equivalent to the Python expression `not o`. On failure, return `-1`.

**PyObject\* PyObject\_Type** (PyObject \*o)

*Return value:* New reference.

When *o* is non-`NULL`, returns a type object corresponding to the object type of object *o*. On failure, raises `SystemError` and returns `NULL`. This is equivalent to the Python expression `type(o)`. This function increments the reference count of the return value. There's really no reason to use this function instead of the common expression `o->ob_type`, which returns a pointer of type `PyTypeObject*`, except when the incremented reference count is needed.

**int PyObject\_TypeCheck** (PyObject \*o, PyTypeObject \*type)

Return true if the object *o* is of type *type* or a subtype of *type*. Both parameters must be non-`NULL`. New in version 2.2.

**Py\_ssize\_t PyObject\_Length** (PyObject \*o)

**Py\_ssize\_t PyObject\_Size** (PyObject \*o)

Return the length of object *o*. If the object *o* provides either the sequence and mapping protocols, the sequence length is returned. On error, `-1` is returned. This is the equivalent to the Python expression `len(o)`. Changed in version 2.5: These functions returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\* PyObject\_GetItem** (PyObject \*o, PyObject \*key)

*Return value:* New reference.

Return element of *o* corresponding to the object *key* or `NULL` on failure. This is the equivalent of the Python expression `o[key]`.

**int PyObject\_SetItem** (PyObject \*o, PyObject \*key, PyObject \*v)  
 Map the object *key* to the value *v*. Returns `-1` on failure. This is the equivalent of the Python statement `o[key] = v`.

**int PyObject\_DelItem** (PyObject \*o, PyObject \*key)  
 Delete the mapping for *key* from *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o[key]`.

**int PyObject\_AsFileDescriptor** (PyObject \*o)  
 Derives a file descriptor from a Python object. If the object is an integer or long integer, its value is returned. If not, the object's `fileno()` method is called if it exists; the method must return an integer or long integer, which is returned as the file descriptor value. Returns `-1` on failure.

**PyObject\* PyObject\_Dir** (PyObject \*o)  
*Return value:* *New reference.*  
 This is equivalent to the Python expression `dir(o)`, returning a (possibly empty) list of strings appropriate for the object argument, or `NULL` if there was an error. If the argument is `NULL`, this is like the Python `dir()`, returning the names of the current locals; in this case, if no execution frame is active then `NULL` is returned but `PyErr_Occurred()` will return false.

**PyObject\* PyObject\_GetIter** (PyObject \*o)  
*Return value:* *New reference.*  
 This is equivalent to the Python expression `iter(o)`. It returns a new iterator for the object argument, or the object itself if the object is already an iterator. Raises `TypeError` and returns `NULL` if the object cannot be iterated.

## 6.2 Number Protocol

**int PyNumber\_Check** (PyObject \*o)  
 Returns 1 if the object *o* provides numeric protocols, and false otherwise. This function always succeeds.

**PyObject\* PyNumber\_Add** (PyObject \*o1, PyObject \*o2)  
*Return value:* *New reference.*  
 Returns the result of adding *o1* and *o2*, or `NULL` on failure. This is the equivalent of the Python expression `o1 + o2`.

**PyObject\* PyNumber\_Subtract** (PyObject \*o1, PyObject \*o2)  
*Return value:* *New reference.*  
 Returns the result of subtracting *o2* from *o1*, or `NULL` on failure. This is the equivalent of the Python expression `o1 - o2`.

**PyObject\* PyNumber\_Multiply** (PyObject \*o1, PyObject \*o2)  
*Return value:* *New reference.*  
 Returns the result of multiplying *o1* and *o2*, or `NULL` on failure. This is the equivalent of the Python expression `o1 * o2`.

**PyObject\* PyNumber\_Divide** (PyObject \*o1, PyObject \*o2)  
*Return value:* *New reference.*  
 Returns the result of dividing *o1* by *o2*, or `NULL` on failure. This is the equivalent of the Python expression `o1 / o2`.

**PyObject\* PyNumber\_FloorDivide** (PyObject \*o1, PyObject \*o2)  
*Return value:* *New reference.*  
 Return the floor of *o1* divided by *o2*, or `NULL` on failure. This is equivalent to the “classic” division of integers. New in version 2.2.

**PyObject\*** **PyNumber\_TrueDivide** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Return a reasonable approximation for the mathematical value of *o1* divided by *o2*, or *NULL* on failure. The return value is “approximate” because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers. New in version 2.2.

**PyObject\*** **PyNumber\_Remainder** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the remainder of dividing *o1* by *o2*, or *NULL* on failure. This is the equivalent of the Python expression `o1 % o2`.

**PyObject\*** **PyNumber\_Divmod** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

See the built-in function `divmod()`. Returns *NULL* on failure. This is the equivalent of the Python expression `divmod(o1, o2)`.

**PyObject\*** **PyNumber\_Power** (PyObject \*o1, PyObject \*o2, PyObject \*o3)

*Return value:* New reference.

See the built-in function `pow()`. Returns *NULL* on failure. This is the equivalent of the Python expression `pow(o1, o2, o3)`, where *o3* is optional. If *o3* is to be ignored, pass `Py_None` in its place (passing *NULL* for *o3* would cause an illegal memory access).

**PyObject\*** **PyNumber\_Negative** (PyObject \*o)

*Return value:* New reference.

Returns the negation of *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `-o`.

**PyObject\*** **PyNumber\_Positive** (PyObject \*o)

*Return value:* New reference.

Returns *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `+o`.

**PyObject\*** **PyNumber\_Absolute** (PyObject \*o)

*Return value:* New reference.

Returns the absolute value of *o*, or *NULL* on failure. This is the equivalent of the Python expression `abs(o)`.

**PyObject\*** **PyNumber\_Invert** (PyObject \*o)

*Return value:* New reference.

Returns the bitwise negation of *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `~o`.

**PyObject\*** **PyNumber\_Lshift** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of left shifting *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 << o2`.

**PyObject\*** **PyNumber\_Rshift** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of right shifting *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 >> o2`.

**PyObject\*** **PyNumber\_And** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise and” of *o1* and *o2* on success and *NULL* on failure. This is the equivalent of the Python expression `o1 & o2`.

**PyObject\*** **PyNumber\_Xor** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise exclusive or” of *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 ^ o2`.

**PyObject\*** **PyNumber\_Or** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise or” of *o1* and *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 | o2`.

**PyObject\*** **PyNumber\_InPlaceAdd** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of adding *o1* and *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 += o2`.

**PyObject\*** **PyNumber\_InPlaceSubtract** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of subtracting *o2* from *o1*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 -= o2`.

**PyObject\*** **PyNumber\_InPlaceMultiply** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of multiplying *o1* and *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 *= o2`.

**PyObject\*** **PyNumber\_InPlaceDivide** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of dividing *o1* by *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 /= o2`.

**PyObject\*** **PyNumber\_InPlaceFloorDivide** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the mathematical floor of dividing *o1* by *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 //= o2`. New in version 2.2.

**PyObject\*** **PyNumber\_InPlaceTrueDivide** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Return a reasonable approximation for the mathematical value of *o1* divided by *o2*, or *NULL* on failure. The return value is “approximate” because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers. The operation is done *in-place* when *o1* supports it. New in version 2.2.

**PyObject\*** **PyNumber\_InPlaceRemainder** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the remainder of dividing *o1* by *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 %= o2`.

**PyObject\*** **PyNumber\_InPlacePower** (PyObject \*o1, PyObject \*o2, PyObject \*o3)

*Return value:* New reference.

See the built-in function `pow()`. Returns *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 **= o2` when *o3* is `Py_None`, or an in-place variant of `pow(o1, o2, o3)` otherwise. If *o3* is to be ignored, pass `Py_None` in its place (passing *NULL* for *o3* would cause an illegal memory access).

**PyObject\*** **PyNumber\_InPlaceLshift** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of left shifting *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 <<= o2`.

**PyObject\*** **PyNumber\_InPlaceRshift** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the result of right shifting *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 >>= o2`.

**PyObject\*** **PyNumber\_InPlaceAnd** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise and” of *o1* and *o2* on success and *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 &= o2`.

**PyObject\*** **PyNumber\_InPlaceXor** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise exclusive or” of *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 ^= o2`.

**PyObject\*** **PyNumber\_InPlaceOr** (PyObject \*o1, PyObject \*o2)

*Return value:* New reference.

Returns the “bitwise or” of *o1* and *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 |= o2`.

**int** **PyNumber\_Coerce** (PyObject \*\*p1, PyObject \*\*p2)

This function takes the addresses of two variables of type `PyObject*`. If the objects pointed to by `*p1` and `*p2` have the same type, increment their reference count and return 0 (success). If the objects can be converted to a common numeric type, replace `*p1` and `*p2` by their converted value (with ‘new’ reference counts), and return 0. If no conversion is possible, or if some other error occurs, return -1 (failure) and don’t increment the reference counts. The call `PyNumber_Coerce(&o1, &o2)` is equivalent to the Python statement `o1, o2 = coerce(o1, o2)`.

**int** **PyNumber\_CoerceEx** (PyObject \*\*p1, PyObject \*\*p2)

This function is similar to `PyNumber_Coerce()`, except that it returns 1 when the conversion is not possible and when no error is raised. Reference counts are still not increased in this case.

**PyObject\*** **PyNumber\_Int** (PyObject \*o)

*Return value:* New reference.

Returns the *o* converted to an integer object on success, or *NULL* on failure. If the argument is outside the integer range a long object will be returned instead. This is the equivalent of the Python expression `int(o)`.

**PyObject\*** **PyNumber\_Long** (PyObject \*o)

*Return value:* New reference.

Returns the *o* converted to a long integer object on success, or *NULL* on failure. This is the equivalent of the Python expression `long(o)`.

**PyObject\*** **PyNumber\_Float** (PyObject \*o)

*Return value:* New reference.

Returns the *o* converted to a float object on success, or *NULL* on failure. This is the equivalent of the Python expression `float(o)`.

**PyObject\*** **PyNumber\_Index** (PyObject \*o)

Returns the *o* converted to a Python int or long on success or *NULL* with a `TypeError` exception raised on failure. New in version 2.5.

**PyObject\*** **PyNumber\_ToBase** (PyObject \*n, int base)

Returns the integer *n* converted to *base* as a string with a base marker of ‘0b’, ‘0o’, or ‘0x’ if applicable. When *base* is not 2, 8, 10, or 16, the format is ‘x#num’ where *x* is the base. If *n* is not an int object, it is converted with `PyNumber_Index()` first. New in version 2.6.

**Py\_ssize\_t** **PyNumber\_Assize\_t** (PyObject \*o, PyObject \*exc)

Returns *o* converted to a `Py_ssize_t` value if *o* can be interpreted as an integer. If *o* can be converted to a Python int or long but the attempt to convert to a `Py_ssize_t` value would raise an `OverflowError`, then the *exc* argument is the type of exception that will be raised (usually `IndexError` or `OverflowError`). If *exc* is *NULL*, then the exception is cleared and the value is clipped to `PY_SSIZE_T_MIN` for a negative integer or `PY_SSIZE_T_MAX` for a positive integer. New in version 2.5.

**int** **PyIndex\_Check** (PyObject \*o)

Returns True if *o* is an index integer (has the `nb_index` slot of the `tp_as_number` structure filled in). New in version 2.5.

## 6.3 Sequence Protocol

`int PySequence_Check (PyObject *o)`

Return 1 if the object provides sequence protocol, and 0 otherwise. This function always succeeds.

`Py_ssize_t PySequence_Size (PyObject *o)`

`Py_ssize_t PySequence_Length (PyObject *o)`

Returns the number of objects in sequence *o* on success, and `-1` on failure. For objects that do not provide sequence protocol, this is equivalent to the Python expression `len(o)`. Changed in version 2.5: These functions returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PySequence_Concat (PyObject *o1, PyObject *o2)`

*Return value:* New reference.

Return the concatenation of *o1* and *o2* on success, and `NULL` on failure. This is the equivalent of the Python expression `o1 + o2`.

`PyObject* PySequence_Repeat (PyObject *o, Py_ssize_t count)`

*Return value:* New reference.

Return the result of repeating sequence object *o* *count* times, or `NULL` on failure. This is the equivalent of the Python expression `o * count`. Changed in version 2.5: This function used an `int` type for *count*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PySequence_InPlaceConcat (PyObject *o1, PyObject *o2)`

*Return value:* New reference.

Return the concatenation of *o1* and *o2* on success, and `NULL` on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python expression `o1 += o2`.

`PyObject* PySequence_InPlaceRepeat (PyObject *o, Py_ssize_t count)`

*Return value:* New reference.

Return the result of repeating sequence object *o* *count* times, or `NULL` on failure. The operation is done *in-place* when *o* supports it. This is the equivalent of the Python expression `o *= count`. Changed in version 2.5: This function used an `int` type for *count*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PySequence_GetItem (PyObject *o, Py_ssize_t i)`

*Return value:* New reference.

Return the *i*th element of *o*, or `NULL` on failure. This is the equivalent of the Python expression `o[i]`. Changed in version 2.5: This function used an `int` type for *i*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PySequence_GetSlice (PyObject *o, Py_ssize_t i1, Py_ssize_t i2)`

*Return value:* New reference.

Return the slice of sequence object *o* between *i1* and *i2*, or `NULL` on failure. This is the equivalent of the Python expression `o[i1:i2]`. Changed in version 2.5: This function used an `int` type for *i1* and *i2*. This might require changes in your code for properly supporting 64-bit systems.

`int PySequence_SetItem (PyObject *o, Py_ssize_t i, PyObject *v)`

Assign object *v* to the *i*th element of *o*. Returns `-1` on failure. This is the equivalent of the Python statement `o[i] = v`. This function *does not* steal a reference to *v*. Changed in version 2.5: This function used an `int` type for *i*. This might require changes in your code for properly supporting 64-bit systems.

`int PySequence_DelItem (PyObject *o, Py_ssize_t i)`

Delete the *i*th element of object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del`

`o[i]`. Changed in version 2.5: This function used an `int` type for `i`. This might require changes in your code for properly supporting 64-bit systems.

`int PySequence_SetSlice (PyObject *o, Py_ssize_t i1, Py_ssize_t i2, PyObject *v)`

Assign the sequence object `v` to the slice in sequence object `o` from `i1` to `i2`. This is the equivalent of the Python statement `o[i1:i2] = v`. Changed in version 2.5: This function used an `int` type for `i1` and `i2`. This might require changes in your code for properly supporting 64-bit systems.

`int PySequence_DelSlice (PyObject *o, Py_ssize_t i1, Py_ssize_t i2)`

Delete the slice in sequence object `o` from `i1` to `i2`. Returns `-1` on failure. This is the equivalent of the Python statement `del o[i1:i2]`. Changed in version 2.5: This function used an `int` type for `i1` and `i2`. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PySequence_Count (PyObject *o, PyObject *value)`

Return the number of occurrences of `value` in `o`, that is, return the number of keys for which `o[key] == value`. On failure, return `-1`. This is equivalent to the Python expression `o.count(value)`. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`int PySequence_Contains (PyObject *o, PyObject *value)`

Determine if `o` contains `value`. If an item in `o` is equal to `value`, return `1`, otherwise return `0`. On error, return `-1`. This is equivalent to the Python expression `value in o`.

`Py_ssize_t PySequence_Index (PyObject *o, PyObject *value)`

Return the first index `i` for which `o[i] == value`. On error, return `-1`. This is equivalent to the Python expression `o.index(value)`. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PySequence_List (PyObject *o)`

*Return value: New reference.*

Return a list object with the same contents as the arbitrary sequence `o`. The returned list is guaranteed to be new.

`PyObject* PySequence_Tuple (PyObject *o)`

*Return value: New reference.*

Return a tuple object with the same contents as the arbitrary sequence `o` or `NULL` on failure. If `o` is a tuple, a new reference will be returned, otherwise a tuple will be constructed with the appropriate contents. This is equivalent to the Python expression `tuple(o)`.

`PyObject* PySequence_Fast (PyObject *o, const char *m)`

*Return value: New reference.*

Returns the sequence `o` as a tuple, unless it is already a tuple or list, in which case `o` is returned. Use `PySequence_Fast_GET_ITEM()` to access the members of the result. Returns `NULL` on failure. If the object is not a sequence, raises `TypeError` with `m` as the message text.

`PyObject* PySequence_Fast_GET_ITEM (PyObject *o, Py_ssize_t i)`

*Return value: Borrowed reference.*

Return the `i`th element of `o`, assuming that `o` was returned by `PySequence_Fast()`, `o` is not `NULL`, and that `i` is within bounds. Changed in version 2.5: This function used an `int` type for `i`. This might require changes in your code for properly supporting 64-bit systems.

`PyObject** PySequence_Fast_ITEMS (PyObject *o)`

Return the underlying array of `PyObject` pointers. Assumes that `o` was returned by `PySequence_Fast()` and `o` is not `NULL`.

Note, if a list gets resized, the reallocation may relocate the items array. So, only use the underlying array pointer in contexts where the sequence cannot change. New in version 2.4.

`PyObject* PySequence_ITEM (PyObject *o, Py_ssize_t i)`

*Return value: New reference.*

Return the `i`th element of `o` or `NULL` on failure. Macro form of `PySequence_GetItem()` but without

checking that `PySequence_Check()` on `o` is true and without adjustment for negative indices. New in version 2.3. Changed in version 2.5: This function used an `int` type for `i`. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PySequence_Fast_GET_SIZE (PyObject *o)`

Returns the length of `o`, assuming that `o` was returned by `PySequence_Fast()` and that `o` is not `NULL`. The size can also be gotten by calling `PySequence_Size()` on `o`, but `PySequence_Fast_GET_SIZE()` is faster because it can assume `o` is a list or tuple.

## 6.4 Mapping Protocol

`int PyMapping_Check (PyObject *o)`

Return 1 if the object provides mapping protocol, and 0 otherwise. This function always succeeds.

`Py_ssize_t PyMapping_Size (PyObject *o)`

`Py_ssize_t PyMapping_Length (PyObject *o)`

Returns the number of keys in object `o` on success, and `-1` on failure. For objects that do not provide mapping protocol, this is equivalent to the Python expression `len(o)`. Changed in version 2.5: These functions returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`int PyMapping_DelItemString (PyObject *o, char *key)`

Remove the mapping for object `key` from the object `o`. Return `-1` on failure. This is equivalent to the Python statement `del o[key]`.

`int PyMapping_DelItem (PyObject *o, PyObject *key)`

Remove the mapping for object `key` from the object `o`. Return `-1` on failure. This is equivalent to the Python statement `del o[key]`.

`int PyMapping_HasKeyString (PyObject *o, char *key)`

On success, return 1 if the mapping object has the key `key` and 0 otherwise. This is equivalent to `o[key]`, returning `True` on success and `False` on an exception. This function always succeeds.

`int PyMapping_HasKey (PyObject *o, PyObject *key)`

Return 1 if the mapping object has the key `key` and 0 otherwise. This is equivalent to `o[key]`, returning `True` on success and `False` on an exception. This function always succeeds.

`PyObject* PyMapping_Keys (PyObject *o)`

*Return value:* New reference.

On success, return a list of the keys in object `o`. On failure, return `NULL`. This is equivalent to the Python expression `o.keys()`.

`PyObject* PyMapping_Values (PyObject *o)`

*Return value:* New reference.

On success, return a list of the values in object `o`. On failure, return `NULL`. This is equivalent to the Python expression `o.values()`.

`PyObject* PyMapping_Items (PyObject *o)`

*Return value:* New reference.

On success, return a list of the items in object `o`, where each item is a tuple containing a key-value pair. On failure, return `NULL`. This is equivalent to the Python expression `o.items()`.

`PyObject* PyMapping_GetItemString (PyObject *o, char *key)`

*Return value:* New reference.

Return element of `o` corresponding to the object `key` or `NULL` on failure. This is the equivalent of the Python expression `o[key]`.

int **PyMapping\_SetItemString** (PyObject \**o*, char \**key*, PyObject \**v*)

Map the object *key* to the value *v* in object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `o[key] = v`.

## 6.5 Iterator Protocol

New in version 2.2. There are only a couple of functions specifically for working with iterators.

int **PyIter\_Check** (PyObject \**o*)

Return true if the object *o* supports the iterator protocol.

PyObject\* **PyIter\_Next** (PyObject \**o*)

*Return value:* New reference.

Return the next value from the iteration *o*. If the object is an iterator, this retrieves the next value from the iteration, and returns `NULL` with no exception set if there are no remaining items. If the object is not an iterator, `TypeError` is raised, or if there is an error in retrieving the item, returns `NULL` and passes along the exception.

To write a loop which iterates over an iterator, the C code should look something like this:

```
PyObject *iterator = PyObject_GetIter(obj);
PyObject *item;
```

```
if (iterator == NULL) {
    /* propagate error */
}

while (item = PyIter_Next(iterator)) {
    /* do something with item */
    ...
    /* release reference when done */
    Py_DECREF(item);
}
```

```
Py_DECREF(iterator);
```

```
if (PyErr_Occurred()) {
    /* propagate error */
}
else {
    /* continue doing useful work */
}
```

## 6.6 Old Buffer Protocol

This section describes the legacy buffer protocol, which has been introduced in Python 1.6. It is still supported but deprecated in the Python 2.x series. Python 3 introduces a new buffer protocol which fixes weaknesses and shortcomings of the protocol, and has been backported to Python 2.6. See *Buffers and Memoryview Objects* for more information.

int **PyObject\_AsCharBuffer** (PyObject \**obj*, const char \*\**buffer*, Py\_ssize\_t \**buffer\_len*)

Returns a pointer to a read-only memory location usable as character-based input. The *obj* argument must support the single-segment character buffer interface. On success, returns `0`, sets *buffer* to the memory location and *buffer\_len* to the buffer length. Returns `-1` and sets a `TypeError` on error. New in version 1.6.Changed

in version 2.5: This function used an `int *` type for `buffer_len`. This might require changes in your code for properly supporting 64-bit systems.

`int PyObject_AsReadBuffer (PyObject *obj, const void **buffer, Py_ssize_t *buffer_len)`

Returns a pointer to a read-only memory location containing arbitrary data. The `obj` argument must support the single-segment readable buffer interface. On success, returns 0, sets `buffer` to the memory location and `buffer_len` to the buffer length. Returns `-1` and sets a `TypeError` on error. New in version 1.6. Changed in version 2.5: This function used an `int *` type for `buffer_len`. This might require changes in your code for properly supporting 64-bit systems.

`int PyObject_CheckReadBuffer (PyObject *o)`

Returns 1 if `o` supports the single-segment readable buffer interface. Otherwise returns 0. New in version 2.2.

`int PyObject_AsWriteBuffer (PyObject *obj, void **buffer, Py_ssize_t *buffer_len)`

Returns a pointer to a writeable memory location. The `obj` argument must support the single-segment, character buffer interface. On success, returns 0, sets `buffer` to the memory location and `buffer_len` to the buffer length. Returns `-1` and sets a `TypeError` on error. New in version 1.6. Changed in version 2.5: This function used an `int *` type for `buffer_len`. This might require changes in your code for properly supporting 64-bit systems.



# CONCRETE OBJECTS LAYER

The functions in this chapter are specific to certain Python object types. Passing them an object of the wrong type is not a good idea; if you receive an object from a Python program and you are not sure that it has the right type, you must perform a type check first; for example, to check that an object is a dictionary, use `PyDict_Check()`. The chapter is structured like the “family tree” of Python object types.

**Warning:** While the functions described in this chapter carefully check the type of the objects which are passed in, many of them do not check for `NULL` being passed instead of a valid object. Allowing `NULL` to be passed in can cause memory access violations and immediate termination of the interpreter.

## 7.1 Fundamental Objects

This section describes Python type objects and the singleton object `None`.

### 7.1.1 Type Objects

#### **PyTypeObject**

The C structure of the objects used to describe built-in types.

#### **PyObject\* PyType\_Type**

This is the type object for type objects; it is the same object as `type` and `types.TypeType` in the Python layer.

#### **int PyType\_Check (PyObject \*o)**

Return true if the object `o` is a type object, including instances of types derived from the standard type object. Return false in all other cases.

#### **int PyType\_CheckExact (PyObject \*o)**

Return true if the object `o` is a type object, but not a subtype of the standard type object. Return false in all other cases. New in version 2.2.

#### **unsigned int PyType\_ClearCache ()**

Clear the internal lookup cache. Return the current version tag. New in version 2.6.

#### **void PyType\_Modified (PyTypeObject \*type)**

Invalidate the internal lookup cache for the type and all of its subtypes. This function must be called after any manual modification of the attributes or base classes of the type. New in version 2.6.

#### **int PyType\_HasFeature (PyObject \*o, int feature)**

Return true if the type object `o` sets the feature `feature`. Type features are denoted by single bit flags.

`int PyType_IS_GC (PyObject *o)`

Return true if the type object includes support for the cycle detector; this tests the type flag `Py_TPFLAGS_HAVE_GC`. New in version 2.0.

`int PyType_IsSubtype (PyTypeObject *a, PyTypeObject *b)`

Return true if *a* is a subtype of *b*. New in version 2.2.

`PyObject* PyType_GenericAlloc (PyTypeObject *type, Py_ssize_t nitems)`

*Return value:* New reference.

New in version 2.2. Changed in version 2.5: This function used an `int` type for *nitems*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PyType_GenericNew (PyTypeObject *type, PyObject *args, PyObject *kwds)`

*Return value:* New reference.

New in version 2.2.

`int PyType_Ready (PyTypeObject *type)`

Finalize a type object. This should be called on all type objects to finish their initialization. This function is responsible for adding inherited slots from a type's base class. Return 0 on success, or return -1 and sets an exception on error. New in version 2.2.

### 7.1.2 The None Object

Note that the `PyTypeObject` for `None` is not directly exposed in the Python/C API. Since `None` is a singleton, testing for object identity (using `==` in C) is sufficient. There is no `PyNone_Check()` function for the same reason.

`PyObject* Py_None`

The Python `None` object, denoting lack of value. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

`Py_RETURN_NONE`

Properly handle returning `Py_None` from within a C function. New in version 2.4.

## 7.2 Numeric Objects

### 7.2.1 Plain Integer Objects

`PyIntObject`

This subtype of `PyObject` represents a Python integer object.

`PyTypeObject PyInt_Type`

This instance of `PyTypeObject` represents the Python plain integer type. This is the same object as `int` and `types.IntType`.

`int PyInt_Check (PyObject *o)`

Return true if *o* is of type `PyInt_Type` or a subtype of `PyInt_Type`. Changed in version 2.2: Allowed subtypes to be accepted.

`int PyInt_CheckExact (PyObject *o)`

Return true if *o* is of type `PyInt_Type`, but not a subtype of `PyInt_Type`. New in version 2.2.

`PyObject* PyInt_FromString (char *str, char **pend, int base)`

*Return value:* New reference.

Return a new `PyIntObject` or `PyLongObject` based on the string value in *str*, which is interpreted according to the radix in *base*. If *pend* is non-`NULL`, *\*pend* will point to the first character in *str* which follows the representation of the number. If *base* is 0, the radix will be determined based on the leading characters of *str*:

if *str* starts with '0x' or '0X', radix 16 will be used; if *str* starts with '0', radix 8 will be used; otherwise radix 10 will be used. If *base* is not 0, it must be between 2 and 36, inclusive. Leading spaces are ignored. If there are no digits, `ValueError` will be raised. If the string represents a number too large to be contained within the machine's `long int` type and overflow warnings are being suppressed, a `PyLongObject` will be returned. If overflow warnings are not being suppressed, `NULL` will be returned in this case.

`PyObject*` **PyInt\_FromLong** (`long ival`)

*Return value:* New reference.

Create a new integer object with a value of *ival*.

The current implementation keeps an array of integer objects for all integers between `-5` and `256`, when you create an `int` in that range you actually just get back a reference to the existing object. So it should be possible to change the value of 1. I suspect the behaviour of Python in this case is undefined. :-)

`PyObject*` **PyInt\_FromSsize\_t** (`Py_ssize_t ival`)

*Return value:* New reference.

Create a new integer object with a value of *ival*. If the value is larger than `LONG_MAX` or smaller than `LONG_MIN`, a long integer object is returned. New in version 2.5.

`PyObject*` **PyInt\_FromSize\_t** (`size_t ival`)

Create a new integer object with a value of *ival*. If the value exceeds `LONG_MAX`, a long integer object is returned. New in version 2.5.

`long` **PyInt\_AsLong** (`PyObject *io`)

Will first attempt to cast the object to a `PyIntObject`, if it is not already one, and then return its value. If there is an error, `-1` is returned, and the caller should check `PyErr_Occurred()` to find out whether there was an error, or whether the value just happened to be `-1`.

`long` **PyInt\_AS\_LONG** (`PyObject *io`)

Return the value of the object *io*. No error checking is performed.

`unsigned long` **PyInt\_AsUnsignedLongMask** (`PyObject *io`)

Will first attempt to cast the object to a `PyIntObject` or `PyLongObject`, if it is not already one, and then return its value as unsigned long. This function does not check for overflow. New in version 2.3.

`unsigned PY_LONG_LONG` **PyInt\_AsUnsignedLongLongMask** (`PyObject *io`)

Will first attempt to cast the object to a `PyIntObject` or `PyLongObject`, if it is not already one, and then return its value as unsigned long long, without checking for overflow. New in version 2.3.

`Py_ssize_t` **PyInt\_AsSsize\_t** (`PyObject *io`)

Will first attempt to cast the object to a `PyIntObject` or `PyLongObject`, if it is not already one, and then return its value as `Py_ssize_t`. New in version 2.5.

`long` **PyInt\_GetMax** ()

Return the system's idea of the largest integer it can handle (`LONG_MAX`, as defined in the system header files).

`int` **PyInt\_ClearFreeList** ()

Clear the integer free list. Return the number of items that could not be freed. New in version 2.6.

## 7.2.2 Boolean Objects

Booleans in Python are implemented as a subclass of integers. There are only two booleans, `Py_False` and `Py_True`. As such, the normal creation and deletion functions don't apply to booleans. The following macros are available, however.

`int` **PyBool\_Check** (`PyObject *o`)

Return true if *o* is of type `PyBool_Type`. New in version 2.3.

### PyObject\* **Py\_False**

The Python `False` object. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

### PyObject\* **Py\_True**

The Python `True` object. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

### **Py\_RETURN\_FALSE**

Return `Py_False` from a function, properly incrementing its reference count. New in version 2.4.

### **Py\_RETURN\_TRUE**

Return `Py_True` from a function, properly incrementing its reference count. New in version 2.4.

### PyObject\* **PyBool\_FromLong** (long *v*)

*Return value:* New reference.

Return a new reference to `Py_True` or `Py_False` depending on the truth value of *v*. New in version 2.3.

## 7.2.3 Long Integer Objects

### **PyLongObject**

This subtype of `PyObject` represents a Python long integer object.

### PyObject **PyLong\_Type**

This instance of `PyTypeObject` represents the Python long integer type. This is the same object as `long` and `types.LongType`.

### int **PyLong\_Check** (PyObject \**p*)

Return true if its argument is a `PyLongObject` or a subtype of `PyLongObject`. Changed in version 2.2: Allowed subtypes to be accepted.

### int **PyLong\_CheckExact** (PyObject \**p*)

Return true if its argument is a `PyLongObject`, but not a subtype of `PyLongObject`. New in version 2.2.

### PyObject\* **PyLong\_FromLong** (long *v*)

*Return value:* New reference.

Return a new `PyLongObject` object from *v*, or `NULL` on failure.

### PyObject\* **PyLong\_FromUnsignedLong** (unsigned long *v*)

*Return value:* New reference.

Return a new `PyLongObject` object from a C `unsigned long`, or `NULL` on failure.

### PyObject\* **PyLong\_FromSsize\_t** (Py\_ssize\_t *v*)

*Return value:* New reference.

Return a new `PyLongObject` object from a C `Py_ssize_t`, or `NULL` on failure. New in version 2.6.

### PyObject\* **PyLong\_FromSize\_t** (size\_t *v*)

*Return value:* New reference.

Return a new `PyLongObject` object from a C `size_t`, or `NULL` on failure. New in version 2.6.

### PyObject\* **PyLong\_FromSsize\_t** (Py\_ssize\_t *v*)

Return a new `PyLongObject` object with a value of *v*, or `NULL` on failure. New in version 2.6.

### PyObject\* **PyLong\_FromSize\_t** (size\_t *v*)

Return a new `PyLongObject` object with a value of *v*, or `NULL` on failure. New in version 2.6.

### PyObject\* **PyLong\_FromLongLong** (PY\_LONG\_LONG *v*)

*Return value:* New reference.

Return a new `PyLongObject` object from a C `long long`, or `NULL` on failure.

**PyObject\*** **PyLong\_FromUnsignedLongLong** (unsigned PY\_LONG\_LONG *v*)

*Return value:* *New reference.*

Return a new `PyLongObject` object from a C `unsigned long long`, or `NULL` on failure.

**PyObject\*** **PyLong\_FromDouble** (double *v*)

*Return value:* *New reference.*

Return a new `PyLongObject` object from the integer part of *v*, or `NULL` on failure.

**PyObject\*** **PyLong\_FromString** (char \**str*, char \*\**pend*, int *base*)

*Return value:* *New reference.*

Return a new `PyLongObject` based on the string value in *str*, which is interpreted according to the radix in *base*. If *pend* is non-`NULL`, *\*pend* will point to the first character in *str* which follows the representation of the number. If *base* is 0, the radix will be determined based on the leading characters of *str*: if *str* starts with `'0x'` or `'0X'`, radix 16 will be used; if *str* starts with `'0'`, radix 8 will be used; otherwise radix 10 will be used. If *base* is not 0, it must be between 2 and 36, inclusive. Leading spaces are ignored. If there are no digits, `ValueError` will be raised.

**PyObject\*** **PyLong\_FromUnicode** (Py\_UNICODE \**u*, Py\_ssize\_t *length*, int *base*)

*Return value:* *New reference.*

Convert a sequence of Unicode digits to a Python long integer value. The first parameter, *u*, points to the first character of the Unicode string, *length* gives the number of characters, and *base* is the radix for the conversion. The radix must be in the range [2, 36]; if it is out of range, `ValueError` will be raised. New in version 1.6. Changed in version 2.5: This function used an `int` for *length*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyLong\_FromVoidPtr** (void \**p*)

*Return value:* *New reference.*

Create a Python integer or long integer from the pointer *p*. The pointer value can be retrieved from the resulting value using `PyLong_AsVoidPtr()`. New in version 1.5.2. Changed in version 2.5: If the integer is larger than `LONG_MAX`, a positive long integer is returned.

long **PyLong\_AsLong** (PyObject \**pylong*)

Return a C `long` representation of the contents of *pylong*. If *pylong* is greater than `LONG_MAX`, an `OverflowError` is raised and `-1` will be returned.

long **PyLong\_AsLongAndOverflow** (PyObject \**pylong*, int \**overflow*)

Return a C `long` representation of the contents of *pylong*. If *pylong* is greater than `LONG_MAX` or less than `LONG_MIN`, set *\*overflow* to 1 or `-1`, respectively, and return `-1`; otherwise, set *\*overflow* to 0. If any other exception occurs (for example a `TypeError` or `MemoryError`), then `-1` will be returned and *\*overflow* will be 0. New in version 2.7.

PY\_LONG\_LONG **PyLong\_AsLongLongAndOverflow** (PyObject \**pylong*, int \**overflow*)

Return a C `long long` representation of the contents of *pylong*. If *pylong* is greater than `PY_LLONG_MAX` or less than `PY_LLONG_MIN`, set *\*overflow* to 1 or `-1`, respectively, and return `-1`; otherwise, set *\*overflow* to 0. If any other exception occurs (for example a `TypeError` or `MemoryError`), then `-1` will be returned and *\*overflow* will be 0. New in version 2.7.

Py\_ssize\_t **PyLong\_AsSsize\_t** (PyObject \**pylong*)

Return a C `Py_ssize_t` representation of the contents of *pylong*. If *pylong* is greater than `PY_SSIZE_T_MAX`, an `OverflowError` is raised and `-1` will be returned. New in version 2.6.

unsigned long **PyLong\_AsUnsignedLong** (PyObject \**pylong*)

Return a C `unsigned long` representation of the contents of *pylong*. If *pylong* is greater than `ULONG_MAX`, an `OverflowError` is raised.

Py\_ssize\_t **PyLong\_AsSsize\_t** (PyObject \**pylong*)

Return a `Py_ssize_t` representation of the contents of *pylong*. If *pylong* is greater than `PY_SSIZE_T_MAX`, an `OverflowError` is raised. New in version 2.6.

`PY_LONG_LONG PyLong_AsLongLong (PyObject *pylong)`

Return a C `long long` from a Python long integer. If *pylong* cannot be represented as a `long long`, an `OverflowError` is raised and `-1` is returned. New in version 2.2.

`unsigned PY_LONG_LONG PyLong_AsUnsignedLongLong (PyObject *pylong)`

Return a C `unsigned long long` from a Python long integer. If *pylong* cannot be represented as an `unsigned long long`, an `OverflowError` is raised and `(unsigned long long)-1` is returned. New in version 2.2. Changed in version 2.7: A negative *pylong* now raises `OverflowError`, not `TypeError`.

`unsigned long PyLong_AsUnsignedLongMask (PyObject *io)`

Return a C `unsigned long` from a Python long integer, without checking for overflow. New in version 2.3.

`unsigned PY_LONG_LONG PyLong_AsUnsignedLongLongMask (PyObject *io)`

Return a C `unsigned long long` from a Python long integer, without checking for overflow. New in version 2.3.

`double PyLong_AsDouble (PyObject *pylong)`

Return a C `double` representation of the contents of *pylong*. If *pylong* cannot be approximately represented as a `double`, an `OverflowError` exception is raised and `-1.0` will be returned.

`void* PyLong_AsVoidPtr (PyObject *pylong)`

Convert a Python integer or long integer *pylong* to a C `void` pointer. If *pylong* cannot be converted, an `OverflowError` will be raised. This is only assured to produce a usable `void` pointer for values created with `PyLong_FromVoidPtr()`. New in version 1.5.2. Changed in version 2.5: For values outside `0..LONG_MAX`, both signed and unsigned integers are accepted.

## 7.2.4 Floating Point Objects

### `PyFloatObject`

This subtype of `PyObject` represents a Python floating point object.

### `PyTypeObject PyFloat_Type`

This instance of `PyTypeObject` represents the Python floating point type. This is the same object as `float` and `types.FloatType`.

`int PyFloat_Check (PyObject *p)`

Return true if its argument is a `PyFloatObject` or a subtype of `PyFloatObject`. Changed in version 2.2: Allowed subtypes to be accepted.

`int PyFloat_CheckExact (PyObject *p)`

Return true if its argument is a `PyFloatObject`, but not a subtype of `PyFloatObject`. New in version 2.2.

`PyObject* PyFloat_FromString (PyObject *str, char **pend)`

*Return value:* New reference.

Create a `PyFloatObject` object based on the string value in *str*, or `NULL` on failure. The *pend* argument is ignored. It remains only for backward compatibility.

`PyObject* PyFloat_FromDouble (double v)`

*Return value:* New reference.

Create a `PyFloatObject` object from *v*, or `NULL` on failure.

`double PyFloat_AsDouble (PyObject *pyfloat)`

Return a C `double` representation of the contents of *pyfloat*. If *pyfloat* is not a Python floating point object but has a `__float__()` method, this method will first be called to convert *pyfloat* into a float. This method returns `-1.0` upon failure, so one should call `PyErr_Occurred()` to check for errors.

`double PyFloat_AS_DOUBLE (PyObject *pyfloat)`

Return a C `double` representation of the contents of *pyfloat*, but without error checking.

`PyObject*` **PyFloat\_GetInfo** (void)

Return a structseq instance which contains information about the precision, minimum and maximum values of a float. It's a thin wrapper around the header file `float.h`. New in version 2.6.

double **PyFloat\_GetMax** ()

Return the maximum representable finite float `DBL_MAX` as C double. New in version 2.6.

double **PyFloat\_GetMin** ()

Return the minimum normalized positive float `DBL_MIN` as C double. New in version 2.6.

int **PyFloat\_ClearFreeList** ()

Clear the float free list. Return the number of items that could not be freed. New in version 2.6.

void **PyFloat\_AsString** (char \*buf, PyFloatObject \*v)

Convert the argument `v` to a string, using the same rules as `str()`. The length of `buf` should be at least 100.

This function is unsafe to call because it writes to a buffer whose length it does not know. Deprecated since version 2.7: Use `PyObject_Str()` or `PyOS_double_to_string()` instead.

void **PyFloat\_AsReprString** (char \*buf, PyFloatObject \*v)

Same as `PyFloat_AsString`, except uses the same rules as `repr()`. The length of `buf` should be at least 100.

This function is unsafe to call because it writes to a buffer whose length it does not know. Deprecated since version 2.7: Use `PyObject_Repr()` or `PyOS_double_to_string()` instead.

## 7.2.5 Complex Number Objects

Python's complex number objects are implemented as two distinct types when viewed from the C API: one is the Python object exposed to Python programs, and the other is a C structure which represents the actual complex number value. The API provides functions for working with both.

### Complex Numbers as C Structures

Note that the functions which accept these structures as parameters and return them as results do so *by value* rather than dereferencing them through pointers. This is consistent throughout the API.

**Py\_complex**

The C structure which corresponds to the value portion of a Python complex number object. Most of the functions for dealing with complex number objects use structures of this type as input or output values, as appropriate. It is defined as:

```
typedef struct {
    double real;
    double imag;
} Py_complex;
```

`Py_complex` **\_Py\_c\_sum** (`Py_complex left`, `Py_complex right`)

Return the sum of two complex numbers, using the C `Py_complex` representation.

`Py_complex` **\_Py\_c\_diff** (`Py_complex left`, `Py_complex right`)

Return the difference between two complex numbers, using the C `Py_complex` representation.

`Py_complex` **\_Py\_c\_neg** (`Py_complex complex`)

Return the negation of the complex number `complex`, using the C `Py_complex` representation.

`Py_complex` **\_Py\_c\_prod** (`Py_complex left`, `Py_complex right`)

Return the product of two complex numbers, using the C `Py_complex` representation.

`Py_complex` **`_Py_c_quot`** (`Py_complex` *dividend*, `Py_complex` *divisor*)  
Return the quotient of two complex numbers, using the C `Py_complex` representation.

If *divisor* is null, this method returns zero and sets `errno` to `EDOM`.

`Py_complex` **`_Py_c_pow`** (`Py_complex` *num*, `Py_complex` *exp*)  
Return the exponentiation of *num* by *exp*, using the C `Py_complex` representation.

If *num* is null and *exp* is not a positive real number, this method returns zero and sets `errno` to `EDOM`.

## Complex Numbers as Python Objects

### **PyComplexObject**

This subtype of `PyObject` represents a Python complex number object.

### `PyTypeObject` **`PyComplex_Type`**

This instance of `PyTypeObject` represents the Python complex number type. It is the same object as `complex` and `types.ComplexType`.

### `int` **`PyComplex_Check`** (`PyObject` \**p*)

Return true if its argument is a `PyComplexObject` or a subtype of `PyComplexObject`. Changed in version 2.2: Allowed subtypes to be accepted.

### `int` **`PyComplex_CheckExact`** (`PyObject` \**p*)

Return true if its argument is a `PyComplexObject`, but not a subtype of `PyComplexObject`. New in version 2.2.

### `PyObject*` **`PyComplex_FromCComplex`** (`Py_complex` *v*)

*Return value:* New reference.

Create a new Python complex number object from a C `Py_complex` value.

### `PyObject*` **`PyComplex_FromDoubles`** (`double` *real*, `double` *imag*)

*Return value:* New reference.

Return a new `PyComplexObject` object from *real* and *imag*.

### `double` **`PyComplex_RealAsDouble`** (`PyObject` \**op*)

Return the real part of *op* as a C `double`.

### `double` **`PyComplex_ImagAsDouble`** (`PyObject` \**op*)

Return the imaginary part of *op* as a C `double`.

### `Py_complex` **`PyComplex_AsCComplex`** (`PyObject` \**op*)

Return the `Py_complex` value of the complex number *op*. Upon failure, this method returns `-1.0` as a real value. Changed in version 2.6: If *op* is not a Python complex number object but has a `__complex__()` method, this method will first be called to convert *op* to a Python complex number object.

## 7.3 Sequence Objects

Generic operations on sequence objects were discussed in the previous chapter; this section deals with the specific kinds of sequence objects that are intrinsic to the Python language.

### 7.3.1 Byte Array Objects

New in version 2.6.

#### **PyByteArrayObject**

This subtype of `PyObject` represents a Python bytearray object.

**PyObject PyByteArray\_Type**

This instance of `PyObject` represents the Python bytearray type; it is the same object as `bytearray` in the Python layer.

**Type check macros**

`int PyByteArray_Check (PyObject *o)`

Return true if the object *o* is a bytearray object or an instance of a subtype of the bytearray type.

`int PyByteArray_CheckExact (PyObject *o)`

Return true if the object *o* is a bytearray object, but not an instance of a subtype of the bytearray type.

**Direct API functions**

`PyObject* PyByteArray_FromObject (PyObject *o)`

Return a new bytearray object from any object, *o*, that implements the buffer protocol.

`PyObject* PyByteArray_FromStringAndSize (const char *string, Py_ssize_t len)`

Create a new bytearray object from *string* and its length, *len*. On failure, *NULL* is returned.

`PyObject* PyByteArray_Concat (PyObject *a, PyObject *b)`

Concat bytearrays *a* and *b* and return a new bytearray with the result.

`Py_ssize_t PyByteArray_Size (PyObject *bytearray)`

Return the size of *bytearray* after checking for a *NULL* pointer.

`char* PyByteArray_AsString (PyObject *bytearray)`

Return the contents of *bytearray* as a char array after checking for a *NULL* pointer.

`int PyByteArray_Resize (PyObject *bytearray, Py_ssize_t len)`

Resize the internal buffer of *bytearray* to *len*.

**Macros**

These macros trade safety for speed and they don't check pointers.

`char* PyByteArray_AS_STRING (PyObject *bytearray)`

Macro version of `PyByteArray_AsString()`.

`Py_ssize_t PyByteArray_GET_SIZE (PyObject *bytearray)`

Macro version of `PyByteArray_Size()`.

**7.3.2 String/Bytes Objects**

These functions raise `TypeError` when expecting a string parameter and are called with a non-string parameter.

---

**Note:** These functions have been renamed to `PyBytes_*` in Python 3.x. Unless otherwise noted, the `PyBytes` functions available in 3.x are aliased to their `PyString_*` equivalents to help porting.

---

**PyStringObject**

This subtype of `PyObject` represents a Python string object.

**PyObject PyString\_Type**

This instance of `PyObject` represents the Python string type; it is the same object as `str` and `types.StringType` in the Python layer.

int **PyString\_Check** (PyObject \*o)

Return true if the object *o* is a string object or an instance of a subtype of the string type. Changed in version 2.2: Allowed subtypes to be accepted.

int **PyString\_CheckExact** (PyObject \*o)

Return true if the object *o* is a string object, but not an instance of a subtype of the string type. New in version 2.2.

PyObject\* **PyString\_FromString** (const char \*v)

*Return value:* New reference.

Return a new string object with a copy of the string *v* as value on success, and *NULL* on failure. The parameter *v* must not be *NULL*; it will not be checked.

PyObject\* **PyString\_FromStringAndSize** (const char \*v, Py\_ssize\_t len)

*Return value:* New reference.

Return a new string object with a copy of the string *v* as value and length *len* on success, and *NULL* on failure. If *v* is *NULL*, the contents of the string are uninitialized. Changed in version 2.5: This function used an *int* type for *len*. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyString\_FromFormat** (const char \*format, ...)

*Return value:* New reference.

Take a C `printf()`-style *format* string and a variable number of arguments, calculate the size of the resulting Python string and return a string with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the *format* string. The following format characters are allowed:

| Format Characters | Type               | Comment                                                                                                                                                                                                       |
|-------------------|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| %%                | <i>n/a</i>         | The literal % character.                                                                                                                                                                                      |
| %c                | int                | A single character, represented as an C int.                                                                                                                                                                  |
| %d                | int                | Exactly equivalent to <code>printf("%d")</code> .                                                                                                                                                             |
| %u                | unsigned int       | Exactly equivalent to <code>printf("%u")</code> .                                                                                                                                                             |
| %ld               | long               | Exactly equivalent to <code>printf("%ld")</code> .                                                                                                                                                            |
| %lu               | unsigned long      | Exactly equivalent to <code>printf("%lu")</code> .                                                                                                                                                            |
| %lld              | long long          | Exactly equivalent to <code>printf("%lld")</code> .                                                                                                                                                           |
| %llu              | unsigned long long | Exactly equivalent to <code>printf("%llu")</code> .                                                                                                                                                           |
| %zd               | Py_ssize_t         | Exactly equivalent to <code>printf("%zd")</code> .                                                                                                                                                            |
| %zu               | size_t             | Exactly equivalent to <code>printf("%zu")</code> .                                                                                                                                                            |
| %i                | int                | Exactly equivalent to <code>printf("%i")</code> .                                                                                                                                                             |
| %x                | int                | Exactly equivalent to <code>printf("%x")</code> .                                                                                                                                                             |
| %s                | char*              | A null-terminated C character array.                                                                                                                                                                          |
| %p                | void*              | The hex representation of a C pointer. Mostly equivalent to <code>printf("%p")</code> except that it is guaranteed to start with the literal 0x regardless of what the platform's <code>printf</code> yields. |

An unrecognized format character causes all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded.

---

**Note:** The “%lld” and “%llu” format specifiers are only available when `HAVE_LONG_LONG` is defined.

---

Changed in version 2.7: Support for “%lld” and “%llu” added.

**PyObject\*** **PyString\_FromFormatV** (const char \*format, va\_list vars)

Return value: New reference.

Identical to `PyString_FromFormat()` except that it takes exactly two arguments.

**Py\_ssize\_t** **PyString\_Size** (PyObject \*string)

Return the length of the string in string object *string*. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

**Py\_ssize\_t** **PyString\_GET\_SIZE** (PyObject \*string)

Macro form of `PyString_Size()` but without error checking. Changed in version 2.5: This macro returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

**char\*** **PyString\_AsString** (PyObject \*string)

Return a NUL-terminated representation of the contents of *string*. The pointer refers to the internal buffer of *string*, not a copy. The data must not be modified in any way, unless the string was just created using `PyString_FromStringAndSize(NULL, size)`. It must not be deallocated. If *string* is a Unicode object, this function computes the default encoding of *string* and operates on that. If *string* is not a string object at all, `PyString_AsString()` returns `NULL` and raises `TypeError`.

**char\*** **PyString\_AS\_STRING** (PyObject \*string)

Macro form of `PyString_AsString()` but without error checking. Only string objects are supported; no Unicode objects should be passed.

**int** **PyString\_AsStringAndSize** (PyObject \*obj, char \*\*buffer, Py\_ssize\_t \*length)

Return a NUL-terminated representation of the contents of the object *obj* through the output variables *buffer* and *length*.

The function accepts both string and Unicode objects as input. For Unicode objects it returns the default encoded version of the object. If *length* is `NULL`, the resulting buffer may not contain NUL characters; if it does, the function returns `-1` and a `TypeError` is raised.

The buffer refers to an internal string buffer of *obj*, not a copy. The data must not be modified in any way, unless the string was just created using `PyString_FromStringAndSize(NULL, size)`. It must not be deallocated. If *string* is a Unicode object, this function computes the default encoding of *string* and operates on that. If *string* is not a string object at all, `PyString_AsStringAndSize()` returns `-1` and raises `TypeError`. Changed in version 2.5: This function used an `int *` type for *length*. This might require changes in your code for properly supporting 64-bit systems.

**void** **PyString\_Concat** (PyObject \*\*string, PyObject \*newpart)

Create a new string object in *\*string* containing the contents of *newpart* appended to *string*; the caller will own the new reference. The reference to the old value of *string* will be stolen. If the new string cannot be created, the old reference to *string* will still be discarded and the value of *\*string* will be set to `NULL`; the appropriate exception will be set.

**void** **PyString\_ConcatAndDel** (PyObject \*\*string, PyObject \*newpart)

Create a new string object in *\*string* containing the contents of *newpart* appended to *string*. This version decrements the reference count of *newpart*.

**int** **\_PyString\_Resize** (PyObject \*\*string, Py\_ssize\_t newsize)

A way to resize a string object even though it is “immutable”. Only use this to build up a brand new string object; don’t use this if the string may already be known in other parts of the code. It is an error to call this function if the `refcount` on the input string object is not one. Pass the address of an existing string object as an `lvalue` (it may be written into), and the new size desired. On success, *\*string* holds the resized string object and `0` is returned; the address in *\*string* may differ from its input value. If the reallocation fails, the original string object at *\*string* is deallocated, *\*string* is set to `NULL`, a memory exception is set, and `-1` is returned. Changed in version 2.5: This function used an `int` type for *newsize*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyString\_Format** (PyObject \*format, PyObject \*args)

*Return value:* New reference.

Return a new string object from *format* and *args*. Analogous to `format % args`. The *args* argument must be a tuple.

void **PyString\_InternInPlace** (PyObject \*\*string)

Intern the argument *\*string* in place. The argument must be the address of a pointer variable pointing to a Python string object. If there is an existing interned string that is the same as *\*string*, it sets *\*string* to it (decrementing the reference count of the old string object and incrementing the reference count of the interned string object), otherwise it leaves *\*string* alone and interns it (incrementing its reference count). (Clarification: even though there is a lot of talk about reference counts, think of this function as reference-count-neutral; you own the object after the call if and only if you owned it before the call.)

---

**Note:** This function is not available in 3.x and does not have a PyBytes alias.

---

**PyObject\*** **PyString\_InternFromString** (const char \*v)

*Return value:* New reference.

A combination of `PyString_FromString()` and `PyString_InternInPlace()`, returning either a new string object that has been interned, or a new (“owned”) reference to an earlier interned string object with the same value.

---

**Note:** This function is not available in 3.x and does not have a PyBytes alias.

---

**PyObject\*** **PyString\_Decode** (const char \*s, Py\_ssize\_t size, const char \*encoding, const char \*errors)

*Return value:* New reference.

Create an object by decoding *size* bytes of the encoded buffer *s* using the codec registered for *encoding*. *encoding* and *errors* have the same meaning as the parameters of the same name in the `unicode()` built-in function. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

---

**Note:** This function is not available in 3.x and does not have a PyBytes alias.

---

Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyString\_AsDecodedObject** (PyObject \*str, const char \*encoding, const char \*errors)

*Return value:* New reference.

Decode a string object by passing it to the codec registered for *encoding* and return the result as Python object. *encoding* and *errors* have the same meaning as the parameters of the same name in the string `encode()` method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

---

**Note:** This function is not available in 3.x and does not have a PyBytes alias.

---

**PyObject\*** **PyString\_Encode** (const char \*s, Py\_ssize\_t size, const char \*encoding, const char \*errors)

*Return value:* New reference.

Encode the `char` buffer of the given *size* by passing it to the codec registered for *encoding* and return a Python object. *encoding* and *errors* have the same meaning as the parameters of the same name in the string `encode()` method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

---

**Note:** This function is not available in 3.x and does not have a PyBytes alias.

---

---

Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyString\_AsEncodedObject** (PyObject \**str*, const char \**encoding*, const char \**errors*)

*Return value:* New reference.

Encode a string object using the codec registered for *encoding* and return the result as Python object. *encoding* and *errors* have the same meaning as the parameters of the same name in the string `encode()` method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

---

**Note:** This function is not available in 3.x and does not have a `PyBytes` alias.

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## 7.3.3 Unicode Objects and Codecs

### Unicode Objects

#### Unicode Type

These are the basic Unicode object types used for the Unicode implementation in Python:

#### **Py\_UNICODE**

This type represents the storage type which is used by Python internally as basis for holding Unicode ordinals. Python's default builds use a 16-bit type for `Py_UNICODE` and store Unicode values internally as UCS2. It is also possible to build a UCS4 version of Python (most recent Linux distributions come with UCS4 builds of Python). These builds then use a 32-bit type for `Py_UNICODE` and store Unicode data internally as UCS4. On platforms where `wchar_t` is available and compatible with the chosen Python Unicode build variant, `Py_UNICODE` is a typedef alias for `wchar_t` to enhance native platform compatibility. On all other platforms, `Py_UNICODE` is a typedef alias for either `unsigned short` (UCS2) or `unsigned long` (UCS4).

Note that UCS2 and UCS4 Python builds are not binary compatible. Please keep this in mind when writing extensions or interfaces.

#### **PyUnicodeObject**

This subtype of `PyObject` represents a Python Unicode object.

#### **PyTypeObject PyUnicode\_Type**

This instance of `PyTypeObject` represents the Python Unicode type. It is exposed to Python code as `unicode` and `types.UnicodeType`.

The following APIs are really C macros and can be used to do fast checks and to access internal read-only data of Unicode objects:

`int` **PyUnicode\_Check** (PyObject \**o*)

Return true if the object *o* is a Unicode object or an instance of a Unicode subtype. Changed in version 2.2: Allowed subtypes to be accepted.

`int` **PyUnicode\_CheckExact** (PyObject \**o*)

Return true if the object *o* is a Unicode object, but not an instance of a subtype. New in version 2.2.

`Py_ssize_t` **PyUnicode\_GET\_SIZE** (PyObject \**o*)

Return the size of the object. *o* has to be a `PyUnicodeObject` (not checked). Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t` **PyUnicode\_GET\_DATA\_SIZE** (PyObject \**o*)

Return the size of the object's internal buffer in bytes. *o* has to be a `PyUnicodeObject` (not checked).

Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`Py_UNICODE*` **PyUnicode\_AS\_UNICODE** (`PyObject *o`)

Return a pointer to the internal `Py_UNICODE` buffer of the object. `o` has to be a `PyUnicodeObject` (not checked).

`const char*` **PyUnicode\_AS\_DATA** (`PyObject *o`)

Return a pointer to the internal buffer of the object. `o` has to be a `PyUnicodeObject` (not checked).

`int` **PyUnicode\_ClearFreeList** ()

Clear the free list. Return the total number of freed items. New in version 2.6.

### Unicode Character Properties

Unicode provides many different character properties. The most often needed ones are available through these macros which are mapped to C functions depending on the Python configuration.

`int` **Py\_UNICODE\_ISSPACE** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a whitespace character.

`int` **Py\_UNICODE\_ISLOWER** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a lowercase character.

`int` **Py\_UNICODE\_ISUPPER** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is an uppercase character.

`int` **Py\_UNICODE\_ISTITLE** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a titlecase character.

`int` **Py\_UNICODE\_ISLINEBREAK** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a linebreak character.

`int` **Py\_UNICODE\_ISDECIMAL** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a decimal character.

`int` **Py\_UNICODE\_ISDIGIT** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a digit character.

`int` **Py\_UNICODE\_ISNUMERIC** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is a numeric character.

`int` **Py\_UNICODE\_ISALPHA** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is an alphabetic character.

`int` **Py\_UNICODE\_ISALNUM** (`Py_UNICODE ch`)

Return 1 or 0 depending on whether `ch` is an alphanumeric character.

These APIs can be used for fast direct character conversions:

`Py_UNICODE` **Py\_UNICODE\_TOLOWER** (`Py_UNICODE ch`)

Return the character `ch` converted to lower case.

`Py_UNICODE` **Py\_UNICODE\_TOUPPER** (`Py_UNICODE ch`)

Return the character `ch` converted to upper case.

`Py_UNICODE` **Py\_UNICODE\_TOTITLE** (`Py_UNICODE ch`)

Return the character `ch` converted to title case.

`int` **Py\_UNICODE\_TODECIMAL** (`Py_UNICODE ch`)

Return the character `ch` converted to a decimal positive integer. Return `-1` if this is not possible. This macro does not raise exceptions.

int **Py\_UNICODE\_TODIGIT** (Py\_UNICODE *ch*)

Return the character *ch* converted to a single digit integer. Return  $-1$  if this is not possible. This macro does not raise exceptions.

double **Py\_UNICODE\_TONUMERIC** (Py\_UNICODE *ch*)

Return the character *ch* converted to a double. Return  $-1.0$  if this is not possible. This macro does not raise exceptions.

### Plain Py\_UNICODE

To create Unicode objects and access their basic sequence properties, use these APIs:

PyObject\* **PyUnicode\_FromUnicode** (const Py\_UNICODE \**u*, Py\_ssize\_t *size*)

*Return value:* New reference.

Create a Unicode object from the Py\_UNICODE buffer *u* of the given size. *u* may be *NULL* which causes the contents to be undefined. It is the user's responsibility to fill in the needed data. The buffer is copied into the new object. If the buffer is not *NULL*, the return value might be a shared object. Therefore, modification of the resulting Unicode object is only allowed when *u* is *NULL*. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyUnicode\_FromStringAndSize** (const char \**u*, Py\_ssize\_t *size*)

*Return value:* New reference.

Create a Unicode object from the char buffer *u*. The bytes will be interpreted as being UTF-8 encoded. *u* may also be *NULL* which causes the contents to be undefined. It is the user's responsibility to fill in the needed data. The buffer is copied into the new object. If the buffer is not *NULL*, the return value might be a shared object. Therefore, modification of the resulting Unicode object is only allowed when *u* is *NULL*. New in version 2.6.

PyObject\* **PyUnicode\_FromString** (const char \**u*)

*Return value:* New reference.

Create a Unicode object from an UTF-8 encoded null-terminated char buffer *u*. New in version 2.6.

PyObject\* **PyUnicode\_FromFormat** (const char \**format*, ...)

*Return value:* New reference.

Take a `C printf()`-style *format* string and a variable number of arguments, calculate the size of the resulting Python unicode string and return a string with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the *format* string. The following format characters are allowed:

| Format Characters | Type              | Comment                                                                                                                                                                                                                    |
|-------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| %%                | <i>n/a</i>        | The literal % character.                                                                                                                                                                                                   |
| %c                | int               | A single character, represented as an C int.                                                                                                                                                                               |
| %d                | int               | Exactly equivalent to <code>printf("%d")</code> .                                                                                                                                                                          |
| %u                | unsigned int      | Exactly equivalent to <code>printf("%u")</code> .                                                                                                                                                                          |
| %ld               | long              | Exactly equivalent to <code>printf("%ld")</code> .                                                                                                                                                                         |
| %lu               | unsigned long     | Exactly equivalent to <code>printf("%lu")</code> .                                                                                                                                                                         |
| %zd               | Py_ssize_t        | Exactly equivalent to <code>printf("%zd")</code> .                                                                                                                                                                         |
| %zu               | size_t            | Exactly equivalent to <code>printf("%zu")</code> .                                                                                                                                                                         |
| %i                | int               | Exactly equivalent to <code>printf("%i")</code> .                                                                                                                                                                          |
| %x                | int               | Exactly equivalent to <code>printf("%x")</code> .                                                                                                                                                                          |
| %s                | char*             | A null-terminated C character array.                                                                                                                                                                                       |
| %p                | void*             | The hex representation of a C pointer. Mostly equivalent to <code>printf("%p")</code> except that it is guaranteed to start with the literal <code>0x</code> regardless of what the platform's <code>printf</code> yields. |
| %U                | PyObject*         | A unicode object.                                                                                                                                                                                                          |
| %V                | PyObject*, char * | A unicode object (which may be <i>NULL</i> ) and a null-terminated C character array as a second parameter (which will be used, if the first parameter is <i>NULL</i> ).                                                   |
| %S                | PyObject*         | The result of calling <code>PyObject_Unicode()</code> .                                                                                                                                                                    |
| %R                | PyObject*         | The result of calling <code>PyObject_Repr()</code> .                                                                                                                                                                       |

An unrecognized format character causes all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded. New in version 2.6.

**PyObject\*** **PyUnicode\_FromFormatV** (const char \**format*, va\_list *vargs*)

*Return value:* New reference.

Identical to `PyUnicode_FromFormat()` except that it takes exactly two arguments. New in version 2.6.

**Py\_UNICODE\*** **PyUnicode\_AsUnicode** (PyObject \**unicode*)

Return a read-only pointer to the Unicode object's internal `Py_UNICODE` buffer, *NULL* if *unicode* is not a Unicode object. Note that the resulting `Py_UNICODE*` string may contain embedded null characters, which would cause the string to be truncated when used in most C functions.

**Py\_ssize\_t** **PyUnicode\_GetSize** (PyObject \**unicode*)

Return the length of the Unicode object. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_FromEncodedObject** (PyObject \**obj*, const char \**encoding*, const char \**errors*)

*Return value:* New reference.

Coerce an encoded object *obj* to an Unicode object and return a reference with incremented refcount.

String and other char buffer compatible objects are decoded according to the given encoding and using the error handling defined by *errors*. Both can be *NULL* to have the interface use the default values (see the next section for details).

All other objects, including Unicode objects, cause a `TypeError` to be set.

The API returns *NULL* if there was an error. The caller is responsible for decref'ing the returned objects.

**PyObject\*** **PyUnicode\_FromObject** (PyObject \*obj)

*Return value:* New reference.

Shortcut for `PyUnicode_FromEncodedObject(obj, NULL, "strict")` which is used throughout the interpreter whenever coercion to Unicode is needed.

If the platform supports `wchar_t` and provides a header file `wchar.h`, Python can interface directly to this type using the following functions. Support is optimized if Python's own `Py_UNICODE` type is identical to the system's `wchar_t`.

### wchar\_t Support

`wchar_t` support for platforms which support it:

**PyObject\*** **PyUnicode\_FromWideChar** (const wchar\_t \*w, Py\_ssize\_t size)

*Return value:* New reference.

Create a Unicode object from the `wchar_t` buffer `w` of the given `size`. Return `NULL` on failure. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**Py\_ssize\_t** **PyUnicode\_AsWideChar** (PyUnicodeObject \*unicode, wchar\_t \*w, Py\_ssize\_t size)

Copy the Unicode object contents into the `wchar_t` buffer `w`. At most `size` `wchar_t` characters are copied (excluding a possibly trailing 0-termination character). Return the number of `wchar_t` characters copied or -1 in case of an error. Note that the resulting `wchar_t` string may or may not be 0-terminated. It is the responsibility of the caller to make sure that the `wchar_t` string is 0-terminated in case this is required by the application. Also, note that the `wchar_t*` string might contain null characters, which would cause the string to be truncated when used with most C functions. Changed in version 2.5: This function returned an `int` type and used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

### Built-in Codecs

Python provides a set of built-in codecs which are written in C for speed. All of these codecs are directly usable via the following functions.

Many of the following APIs take two arguments encoding and errors, and they have the same semantics as the ones of the built-in `unicode()` Unicode object constructor.

Setting encoding to `NULL` causes the default encoding to be used which is ASCII. The file system calls should use `Py_FileSystemDefaultEncoding` as the encoding for file names. This variable should be treated as read-only: on some systems, it will be a pointer to a static string, on others, it will change at run-time (such as when the application invokes `setlocale`).

Error handling is set by errors which may also be set to `NULL` meaning to use the default handling defined for the codec. Default error handling for all built-in codecs is "strict" (`ValueError` is raised).

The codecs all use a similar interface. Only deviation from the following generic ones are documented for simplicity.

### Generic Codecs

These are the generic codec APIs:

**PyObject\*** **PyUnicode\_Decompile** (const char \*s, Py\_ssize\_t size, const char \*encoding, const char \*errors)

*Return value:* New reference.

Create a Unicode object by decoding `size` bytes of the encoded string `s`. `encoding` and `errors` have the same meaning as the parameters of the same name in the `unicode()` built-in function. The codec to be used is looked up using the Python codec registry. Return `NULL` if an exception was raised by the codec. Changed

in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_Encode** (const **Py\_UNICODE** \*s, Py\_ssize\_t size, const char \*encoding, const char \*errors)

*Return value: New reference.*

Encode the **Py\_UNICODE** buffer `s` of the given `size` and return a Python string object. `encoding` and `errors` have the same meaning as the parameters of the same name in the Unicode `encode()` method. The codec to be used is looked up using the Python codec registry. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsEncodedString** (PyObject \*unicode, const char \*encoding, const char \*errors)

*Return value: New reference.*

Encode a Unicode object and return the result as Python string object. `encoding` and `errors` have the same meaning as the parameters of the same name in the Unicode `encode()` method. The codec to be used is looked up using the Python codec registry. Return `NULL` if an exception was raised by the codec.

### UTF-8 Codecs

These are the UTF-8 codec APIs:

**PyObject\*** **PyUnicode\_DecodeUTF8** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value: New reference.*

Create a Unicode object by decoding `size` bytes of the UTF-8 encoded string `s`. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_DecodeUTF8Stateful** (const char \*s, Py\_ssize\_t size, const char \*errors, Py\_ssize\_t \*consumed)

*Return value: New reference.*

If `consumed` is `NULL`, behave like `PyUnicode_DecodeUTF8()`. If `consumed` is not `NULL`, trailing incomplete UTF-8 byte sequences will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in `consumed`. New in version 2.4. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_EncodeUTF8** (const **Py\_UNICODE** \*s, Py\_ssize\_t size, const char \*errors)

*Return value: New reference.*

Encode the **Py\_UNICODE** buffer `s` of the given `size` using UTF-8 and return a Python string object. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsUTF8String** (PyObject \*unicode)

*Return value: New reference.*

Encode a Unicode object using UTF-8 and return the result as Python string object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

### UTF-32 Codecs

These are the UTF-32 codec APIs:

**PyObject\*** **PyUnicode\_DecodeUTF32** (const char \*s, Py\_ssize\_t size, const char \*errors, int \*byteorder)

Decode `size` bytes from a UTF-32 encoded buffer string and return the corresponding Unicode object. `errors` (if non-`NULL`) defines the error handling. It defaults to “strict”.

If *byteorder* is non-*NULL*, the decoder starts decoding using the given byte order:

```
*byteorder == -1: little endian
*byteorder == 0:  native order
*byteorder == 1:  big endian
```

If *\*byteorder* is zero, and the first four bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If *\*byteorder* is -1 or 1, any byte order mark is copied to the output.

After completion, *\*byteorder* is set to the current byte order at the end of input data.

In a narrow build codepoints outside the BMP will be decoded as surrogate pairs.

If *byteorder* is *NULL*, the codec starts in native order mode.

Return *NULL* if an exception was raised by the codec. New in version 2.6.

**PyObject\*** **PyUnicode\_DecodeUTF32Stateful** (const char \*s, Py\_ssize\_t size, const char \*errors, int \*byteorder, Py\_ssize\_t \*consumed)

If *consumed* is *NULL*, behave like `PyUnicode_DecodeUTF32()`. If *consumed* is not *NULL*, `PyUnicode_DecodeUTF32Stateful()` will not treat trailing incomplete UTF-32 byte sequences (such as a number of bytes not divisible by four) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*. New in version 2.6.

**PyObject\*** **PyUnicode\_EncodeUTF32** (const Py\_UNICODE \*s, Py\_ssize\_t size, const char \*errors, int byteorder)

Return a Python bytes object holding the UTF-32 encoded value of the Unicode data in *s*. Output is written according to the following byte order:

```
byteorder == -1: little endian
byteorder == 0:  native byte order (writes a BOM mark)
byteorder == 1:  big endian
```

If *byteorder* is 0, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If `Py_UNICODE_WIDE` is not defined, surrogate pairs will be output as a single codepoint.

Return *NULL* if an exception was raised by the codec. New in version 2.6.

**PyObject\*** **PyUnicode\_AsUTF32String** (PyObject \*unicode)

Return a Python string using the UTF-32 encoding in native byte order. The string always starts with a BOM mark. Error handling is “strict”. Return *NULL* if an exception was raised by the codec. New in version 2.6.

## UTF-16 Codecs

These are the UTF-16 codec APIs:

**PyObject\*** **PyUnicode\_DecodeUTF16** (const char \*s, Py\_ssize\_t size, const char \*errors, int \*byteorder)

*Return value:* *New reference.*

Decode *size* bytes from a UTF-16 encoded buffer string and return the corresponding Unicode object. *errors* (if non-*NULL*) defines the error handling. It defaults to “strict”.

If *byteorder* is non-*NULL*, the decoder starts decoding using the given byte order:

```
*byteorder == -1: little endian
*byteorder == 0:  native order
*byteorder == 1:  big endian
```

If `*byteorder` is zero, and the first two bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If `*byteorder` is `-1` or `1`, any byte order mark is copied to the output (where it will result in either a `\ufeff` or a `\ufffe` character).

After completion, `*byteorder` is set to the current byte order at the end of input data.

If `byteorder` is `NULL`, the codec starts in native order mode.

Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_DecodeUTF16Stateful** (const char \*s, Py\_ssize\_t size, const char \*errors, int \*byteorder, Py\_ssize\_t \*consumed)

*Return value:* New reference.

If `consumed` is `NULL`, behave like `PyUnicode_DecodeUTF16()`. If `consumed` is not `NULL`, `PyUnicode_DecodeUTF16Stateful()` will not treat trailing incomplete UTF-16 byte sequences (such as an odd number of bytes or a split surrogate pair) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in `consumed`. New in version 2.4. Changed in version 2.5: This function used an `int` type for `size` and an `int *` type for `consumed`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_EncodeUTF16** (const Py\_UNICODE \*s, Py\_ssize\_t size, const char \*errors, int byteorder)

*Return value:* New reference.

Return a Python string object holding the UTF-16 encoded value of the Unicode data in `s`. Output is written according to the following byte order:

```
byteorder == -1: little endian
byteorder == 0: native byte order (writes a BOM mark)
byteorder == 1: big endian
```

If `byteorder` is `0`, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If `Py_UNICODE_WIDE` is defined, a single `Py_UNICODE` value may get represented as a surrogate pair. If it is not defined, each `Py_UNICODE` value is interpreted as an UCS-2 character.

Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsUTF16String** (PyObject \*unicode)

*Return value:* New reference.

Return a Python string using the UTF-16 encoding in native byte order. The string always starts with a BOM mark. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

### UTF-7 Codecs

These are the UTF-7 codec APIs:

**PyObject\*** **PyUnicode\_DecodeUTF7** (const char \*s, Py\_ssize\_t size, const char \*errors)

Create a Unicode object by decoding `size` bytes of the UTF-7 encoded string `s`. Return `NULL` if an exception was raised by the codec.

**PyObject\*** **PyUnicode\_DecodeUTF7Stateful** (const char \*s, Py\_ssize\_t size, const char \*errors, Py\_ssize\_t \*consumed)

If `consumed` is `NULL`, behave like `PyUnicode_DecodeUTF7()`. If `consumed` is not `NULL`, trailing incomplete UTF-7 base-64 sections will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in `consumed`.

**PyObject\* PyUnicode\_EncodeUTF7** (const Py\_UNICODE \*s, Py\_ssize\_t size, int base64SetO, int base64WhiteSpace, const char \*errors)

Encode the Py\_UNICODE buffer of the given size using UTF-7 and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

If *base64SetO* is nonzero, “Set O” (punctuation that has no otherwise special meaning) will be encoded in base-64. If *base64WhiteSpace* is nonzero, whitespace will be encoded in base-64. Both are set to zero for the Python “utf-7” codec.

### Unicode-Escape Codecs

These are the “Unicode Escape” codec APIs:

**PyObject\* PyUnicode\_DecompileUnicodeEscape** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value: New reference.*

Create a Unicode object by decoding *size* bytes of the Unicode-Escape encoded string *s*. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\* PyUnicode\_EncodeUnicodeEscape** (const Py\_UNICODE \*s, Py\_ssize\_t size)

*Return value: New reference.*

Encode the Py\_UNICODE buffer of the given *size* using Unicode-Escape and return a Python string object. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\* PyUnicode\_AsUnicodeEscapeString** (PyObject \*unicode)

*Return value: New reference.*

Encode a Unicode object using Unicode-Escape and return the result as Python string object. Error handling is “strict”. Return *NULL* if an exception was raised by the codec.

### Raw-Unicode-Escape Codecs

These are the “Raw Unicode Escape” codec APIs:

**PyObject\* PyUnicode\_DecompileRawUnicodeEscape** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value: New reference.*

Create a Unicode object by decoding *size* bytes of the Raw-Unicode-Escape encoded string *s*. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\* PyUnicode\_EncodeRawUnicodeEscape** (const Py\_UNICODE \*s, Py\_ssize\_t size, const char \*errors)

*Return value: New reference.*

Encode the Py\_UNICODE buffer of the given *size* using Raw-Unicode-Escape and return a Python string object. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\* PyUnicode\_AsRawUnicodeEscapeString** (PyObject \*unicode)

*Return value: New reference.*

Encode a Unicode object using Raw-Unicode-Escape and return the result as Python string object. Error handling is “strict”. Return *NULL* if an exception was raised by the codec.

### Latin-1 Codecs

These are the Latin-1 codec APIs: Latin-1 corresponds to the first 256 Unicode ordinals and only these are accepted by the codecs during encoding.

**PyObject\*** **PyUnicode\_DecodeLatin1** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value:* New reference.

Create a Unicode object by decoding *size* bytes of the Latin-1 encoded string *s*. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_EncodeLatin1** (const Py\_UNICODE \*s, Py\_ssize\_t size, const char \*errors)

*Return value:* New reference.

Encode the `Py_UNICODE` buffer of the given *size* using Latin-1 and return a Python string object. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsLatin1String** (PyObject \*unicode)

*Return value:* New reference.

Encode a Unicode object using Latin-1 and return the result as Python string object. Error handling is “strict”. Return *NULL* if an exception was raised by the codec.

### ASCII Codecs

These are the ASCII codec APIs. Only 7-bit ASCII data is accepted. All other codes generate errors.

**PyObject\*** **PyUnicode\_DecodeASCII** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value:* New reference.

Create a Unicode object by decoding *size* bytes of the ASCII encoded string *s*. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_EncodeASCII** (const Py\_UNICODE \*s, Py\_ssize\_t size, const char \*errors)

*Return value:* New reference.

Encode the `Py_UNICODE` buffer of the given *size* using ASCII and return a Python string object. Return *NULL* if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsASCIIString** (PyObject \*unicode)

*Return value:* New reference.

Encode a Unicode object using ASCII and return the result as Python string object. Error handling is “strict”. Return *NULL* if an exception was raised by the codec.

### Character Map Codecs

This codec is special in that it can be used to implement many different codecs (and this is in fact what was done to obtain most of the standard codecs included in the `encodings` package). The codec uses mapping to encode and decode characters.

Decoding mappings must map single string characters to single Unicode characters, integers (which are then interpreted as Unicode ordinals) or *None* (meaning “undefined mapping” and causing an error).

Encoding mappings must map single Unicode characters to single string characters, integers (which are then interpreted as Latin-1 ordinals) or *None* (meaning “undefined mapping” and causing an error).

The mapping objects provided must only support the `__getitem__` mapping interface.

If a character lookup fails with a `LookupError`, the character is copied as-is meaning that its ordinal value will be interpreted as Unicode or Latin-1 ordinal resp. Because of this, mappings only need to contain those mappings which map characters to different code points.

These are the mapping codec APIs:

**PyObject\*** **PyUnicode\_DecodeCharmap** (const char \*s, Py\_ssize\_t size, PyObject \*mapping, const char \*errors)

*Return value:* New reference.

Create a Unicode object by decoding *size* bytes of the encoded string *s* using the given *mapping* object. Return `NULL` if an exception was raised by the codec. If *mapping* is `NULL` latin-1 decoding will be done. Else it can be a dictionary mapping byte or a unicode string, which is treated as a lookup table. Byte values greater than the length of the string and U+FFFE “characters” are treated as “undefined mapping”. Changed in version 2.4: Allowed unicode string as mapping argument. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_EncodeCharmap** (const Py\_UNICODE \*s, Py\_ssize\_t size, PyObject \*mapping, const char \*errors)

*Return value:* New reference.

Encode the `Py_UNICODE` buffer of the given *size* using the given *mapping* object and return a Python string object. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_AsCharmapString** (PyObject \*unicode, PyObject \*mapping)

*Return value:* New reference.

Encode a Unicode object using the given *mapping* object and return the result as Python string object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

The following codec API is special in that maps Unicode to Unicode.

**PyObject\*** **PyUnicode\_TranslateCharmap** (const Py\_UNICODE \*s, Py\_ssize\_t size, PyObject \*table, const char \*errors)

*Return value:* New reference.

Translate a `Py_UNICODE` buffer of the given *size* by applying a character mapping *table* to it and return the resulting Unicode object. Return `NULL` when an exception was raised by the codec.

The *mapping* table must map Unicode ordinal integers to Unicode ordinal integers or `None` (causing deletion of the character).

Mapping tables need only provide the `__getitem__()` interface; dictionaries and sequences work well. Unmapped character ordinals (ones which cause a `LookupError`) are left untouched and are copied as-is. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

### MBCS codecs for Windows

These are the MBCS codec APIs. They are currently only available on Windows and use the Win32 MBCS converters to implement the conversions. Note that MBCS (or DBCS) is a class of encodings, not just one. The target encoding is defined by the user settings on the machine running the codec.

**PyObject\*** **PyUnicode\_DecodeMBCS** (const char \*s, Py\_ssize\_t size, const char \*errors)

*Return value:* New reference.

Create a Unicode object by decoding *size* bytes of the MBCS encoded string *s*. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** **PyUnicode\_DecodeMBCSStateful** (const char \*s, int size, const char \*errors, int \*consumed)

If *consumed* is `NULL`, behave like `PyUnicode_DecodeMBCS()`. If *consumed* is not `NULL`,

`PyUnicode_DecomposeMBCSStateful()` will not decode trailing lead byte and the number of bytes that have been decoded will be stored in `consumed`. New in version 2.5.

**PyObject\*** `PyUnicode_EncodeMBCS` (const `Py_UNICODE` \*s, `Py_ssize_t` size, const char \*errors)

*Return value:* New reference.

Encode the `Py_UNICODE` buffer of the given `size` using MBCS and return a Python string object. Return `NULL` if an exception was raised by the codec. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** `PyUnicode_AsMBCSString` (PyObject \*unicode)

*Return value:* New reference.

Encode a Unicode object using MBCS and return the result as Python string object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

### Methods & Slots

### Methods and Slot Functions

The following APIs are capable of handling Unicode objects and strings on input (we refer to them as strings in the descriptions) and return Unicode objects or integers as appropriate.

They all return `NULL` or `-1` if an exception occurs.

**PyObject\*** `PyUnicode_Concat` (PyObject \*left, PyObject \*right)

*Return value:* New reference.

Concat two strings giving a new Unicode string.

**PyObject\*** `PyUnicode_Split` (PyObject \*s, PyObject \*sep, `Py_ssize_t` maxsplit)

*Return value:* New reference.

Split a string giving a list of Unicode strings. If `sep` is `NULL`, splitting will be done at all whitespace substrings. Otherwise, splits occur at the given separator. At most `maxsplit` splits will be done. If negative, no limit is set. Separators are not included in the resulting list. Changed in version 2.5: This function used an `int` type for `maxsplit`. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** `PyUnicode_Splitlines` (PyObject \*s, int keepend)

*Return value:* New reference.

Split a Unicode string at line breaks, returning a list of Unicode strings. CRLF is considered to be one line break. If `keepend` is 0, the Line break characters are not included in the resulting strings.

**PyObject\*** `PyUnicode_Translate` (PyObject \*str, PyObject \*table, const char \*errors)

*Return value:* New reference.

Translate a string by applying a character mapping table to it and return the resulting Unicode object.

The mapping table must map Unicode ordinal integers to Unicode ordinal integers or `None` (causing deletion of the character).

Mapping tables need only provide the `__getitem__()` interface; dictionaries and sequences work well. Unmapped character ordinals (ones which cause a `LookupError`) are left untouched and are copied as-is.

`errors` has the usual meaning for codecs. It may be `NULL` which indicates to use the default error handling.

**PyObject\*** `PyUnicode_Join` (PyObject \*separator, PyObject \*seq)

*Return value:* New reference.

Join a sequence of strings using the given `separator` and return the resulting Unicode string.

**int** `PyUnicode_Tailmatch` (PyObject \*str, PyObject \*substr, `Py_ssize_t` start, `Py_ssize_t` end, int direction)

Return 1 if `substr` matches `str[start:end]` at the given tail end (`direction == -1` means to do a prefix match, `direction == 1` a suffix match), 0 otherwise. Return `-1` if an error occurred. Changed in version 2.5: This

function used an `int` type for *start* and *end*. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PyUnicode_Find` (`PyObject *str`, `PyObject *substr`, `Py_ssize_t start`, `Py_ssize_t end`, `int direction`)

Return the first position of *substr* in `str[start:end]` using the given *direction* (*direction* == 1 means to do a forward search, *direction* == -1 a backward search). The return value is the index of the first match; a value of -1 indicates that no match was found, and -2 indicates that an error occurred and an exception has been set. Changed in version 2.5: This function used an `int` type for *start* and *end*. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PyUnicode_Count` (`PyObject *str`, `PyObject *substr`, `Py_ssize_t start`, `Py_ssize_t end`)

Return the number of non-overlapping occurrences of *substr* in `str[start:end]`. Return -1 if an error occurred. Changed in version 2.5: This function returned an `int` type and used an `int` type for *start* and *end*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PyUnicode_Replace` (`PyObject *str`, `PyObject *substr`, `PyObject *replstr`, `Py_ssize_t maxcount`)

*Return value:* New reference.

Replace at most *maxcount* occurrences of *substr* in *str* with *replstr* and return the resulting Unicode object. *maxcount* == -1 means replace all occurrences. Changed in version 2.5: This function used an `int` type for *maxcount*. This might require changes in your code for properly supporting 64-bit systems.

`int PyUnicode_Compare` (`PyObject *left`, `PyObject *right`)

Compare two strings and return -1, 0, 1 for less than, equal, and greater than, respectively.

`int PyUnicode_RichCompare` (`PyObject *left`, `PyObject *right`, `int op`)

Rich compare two unicode strings and return one of the following:

- `NULL` in case an exception was raised
- `Py_True` or `Py_False` for successful comparisons
- `Py_NotImplemented` in case the type combination is unknown

Note that `Py_EQ` and `Py_NE` comparisons can cause a `UnicodeWarning` in case the conversion of the arguments to Unicode fails with a `UnicodeDecodeError`.

Possible values for *op* are `Py_GT`, `Py_GE`, `Py_EQ`, `Py_NE`, `Py_LT`, and `Py_LE`.

`PyObject* PyUnicode_Format` (`PyObject *format`, `PyObject *args`)

*Return value:* New reference.

Return a new string object from *format* and *args*; this is analogous to `format % args`. The *args* argument must be a tuple.

`int PyUnicode_Contains` (`PyObject *container`, `PyObject *element`)

Check whether *element* is contained in *container* and return true or false accordingly.

*element* has to coerce to a one element Unicode string. -1 is returned if there was an error.

### 7.3.4 Buffers and Memoryview Objects

Python objects implemented in C can export a group of functions called the “buffer interface.” These functions can be used by an object to expose its data in a raw, byte-oriented format. Clients of the object can use the buffer interface to access the object data directly, without needing to copy it first.

Two examples of objects that support the buffer interface are strings and arrays. The string object exposes the character contents in the buffer interface’s byte-oriented form. An array can also expose its contents, but it should be noted that array elements may be multi-byte values.

An example user of the buffer interface is the file object's `write()` method. Any object that can export a series of bytes through the buffer interface can be written to a file. There are a number of format codes to `PyArg_ParseTuple()` that operate against an object's buffer interface, returning data from the target object.

Starting from version 1.6, Python has been providing Python-level buffer objects and a C-level buffer API so that any built-in or user-defined type can expose its characteristics. Both, however, have been deprecated because of various shortcomings, and have been officially removed in Python 3 in favour of a new C-level buffer API and a new Python-level object named `memoryview`.

The new buffer API has been backported to Python 2.6, and the `memoryview` object has been backported to Python 2.7. It is strongly advised to use them rather than the old APIs, unless you are blocked from doing so for compatibility reasons.

### The new-style `Py_buffer` struct

#### `Py_buffer`

`void *buf`

A pointer to the start of the memory for the object.

`Py_ssize_t len`

The total length of the memory in bytes.

`int readonly`

An indicator of whether the buffer is read only.

`const char *format`

A `NULL` terminated string in `struct` module style syntax giving the contents of the elements available through the buffer. If this is `NULL`, "B" (unsigned bytes) is assumed.

`int ndim`

The number of dimensions the memory represents as a multi-dimensional array. If it is 0, `strides` and `suboffsets` must be `NULL`.

`Py_ssize_t *shape`

An array of `Py_ssize_t`s the length of `ndim` giving the shape of the memory as a multi-dimensional array. Note that `((*shape)[0] * ... * (*shape)[ndims-1]) * itemsize` should be equal to `len`.

`Py_ssize_t *strides`

An array of `Py_ssize_t`s the length of `ndim` giving the number of bytes to skip to get to a new element in each dimension.

`Py_ssize_t *suboffsets`

An array of `Py_ssize_t`s the length of `ndim`. If these suboffset numbers are greater than or equal to 0, then the value stored along the indicated dimension is a pointer and the suboffset value dictates how many bytes to add to the pointer after de-referencing. A suboffset value that is negative indicates that no de-referencing should occur (striding in a contiguous memory block).

Here is a function that returns a pointer to the element in an N-D array pointed to by an N-dimensional index when there are both non-`NULL` `strides` and `suboffsets`:

```
void *get_item_pointer(int ndim, void *buf, Py_ssize_t *strides,
    Py_ssize_t *suboffsets, Py_ssize_t *indices) {
    char *pointer = (char*)buf;
    int i;
    for (i = 0; i < ndim; i++) {
        pointer += strides[i] * indices[i];
    }
}
```

```

        if (suboffsets[i] >=0 ) {
            pointer = *((char**)pointer) + suboffsets[i];
        }
    }
    return (void*)pointer;
}

```

**Py\_ssize\_t itemsize**

This is a storage for the itemsize (in bytes) of each element of the shared memory. It is technically un-necessary as it can be obtained using `PyBuffer_SizeFromFormat()`, however an exporter may know this information without parsing the format string and it is necessary to know the itemsize for proper interpretation of striding. Therefore, storing it is more convenient and faster.

**void \*internal**

This is for use internally by the exporting object. For example, this might be re-cast as an integer by the exporter and used to store flags about whether or not the shape, strides, and suboffsets arrays must be freed when the buffer is released. The consumer should never alter this value.

**Buffer related functions****int PyObject\_CheckBuffer (PyObject \*obj)**

Return 1 if *obj* supports the buffer interface otherwise 0.

**int PyObject\_GetBuffer (PyObject \*obj, Py\_buffer \*view, int flags)**

Export *obj* into a `Py_buffer`, *view*. These arguments must never be *NULL*. The *flags* argument is a bit field indicating what kind of buffer the caller is prepared to deal with and therefore what kind of buffer the exporter is allowed to return. The buffer interface allows for complicated memory sharing possibilities, but some caller may not be able to handle all the complexity but may want to see if the exporter will let them take a simpler view to its memory.

Some exporters may not be able to share memory in every possible way and may need to raise errors to signal to some consumers that something is just not possible. These errors should be a `BufferError` unless there is another error that is actually causing the problem. The exporter can use *flags* information to simplify how much of the `Py_buffer` structure is filled in with non-default values and/or raise an error if the object can't support a simpler view of its memory.

0 is returned on success and -1 on error.

The following table gives possible values to the *flags* arguments.

| Flag                                                             | Description                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PyBUF_SIMPLE                                                     | This is the default flag state. The returned buffer may or may not have writable memory. The format of the data will be assumed to be unsigned bytes. This is a “stand-alone” flag constant. It never needs to be ‘I’d to the others. The exporter will raise an error if it cannot provide such a contiguous buffer of bytes.                                                           |
| PyBUF_WRITABLE                                                   | The returned buffer must be writable. If it is not writable, then raise an error.                                                                                                                                                                                                                                                                                                        |
| PyBUF_STRIDES                                                    | This implies PyBUF_ND. The returned buffer must provide strides information (i.e. the strides cannot be NULL). This would be used when the consumer can handle strided, discontinuous arrays. Handling strides automatically assumes you can handle shape. The exporter can raise an error if a strided representation of the data is not possible (i.e. without the suboffsets).        |
| PyBUF_ND                                                         | The returned buffer must provide shape information. The memory will be assumed C-style contiguous (last dimension varies the fastest). The exporter may raise an error if it cannot provide this kind of contiguous buffer. If this is not given then shape will be NULL.                                                                                                                |
| PyBUF_C_CONTIGUOUS<br>PyBUF_F_CONTIGUOUS<br>PyBUF_ANY_CONTIGUOUS | These flags indicate that the contiguity returned buffer must be respectively, C-contiguous (last dimension varies the fastest), Fortran contiguous (first dimension varies the fastest) or either one. All of these flags imply PyBUF_STRIDES and guarantee that the strides buffer info structure will be filled in correctly.                                                         |
| PyBUF_INDIRECT                                                   | This flag indicates the returned buffer must have suboffsets information (which can be NULL if no suboffsets are needed). This can be used when the consumer can handle indirect array referencing implied by these suboffsets. This implies PyBUF_STRIDES.                                                                                                                              |
| PyBUF_FORMAT                                                     | The returned buffer must have true format information if this flag is provided. This would be used when the consumer is going to be checking for what ‘kind’ of data is actually stored. An exporter should always be able to provide this information if requested. If format is not explicitly requested then the format must be returned as NULL (which means ‘B’, or unsigned bytes) |
| PyBUF_STRIDED                                                    | This is equivalent to (PyBUF_STRIDES   PyBUF_WRITABLE).                                                                                                                                                                                                                                                                                                                                  |
| PyBUF_STRIDED_RO                                                 | This is equivalent to (PyBUF_STRIDES).                                                                                                                                                                                                                                                                                                                                                   |
| PyBUF_RECORDS                                                    | This is equivalent to (PyBUF_STRIDES   PyBUF_FORMAT   PyBUF_WRITABLE).                                                                                                                                                                                                                                                                                                                   |
| PyBUF_RECORDS_RO                                                 | This is equivalent to (PyBUF_STRIDES   PyBUF_FORMAT).                                                                                                                                                                                                                                                                                                                                    |
| PyBUF_FULL                                                       | This is equivalent to (PyBUF_INDIRECT   PyBUF_FORMAT   PyBUF_WRITABLE).                                                                                                                                                                                                                                                                                                                  |
| PyBUF_FULL_RO                                                    | This is equivalent to (PyBUF_INDIRECT   PyBUF_FORMAT).                                                                                                                                                                                                                                                                                                                                   |
| PyBUF_CONTIG                                                     | This is equivalent to (PyBUF_ND   PyBUF_WRITABLE).                                                                                                                                                                                                                                                                                                                                       |
| PyBUF_CONTIG_RO                                                  | This is equivalent to (PyBUF_ND).                                                                                                                                                                                                                                                                                                                                                        |

void **PyBuffer\_Release** (Py\_buffer \*view)

Release the buffer *view*. This should be called when the buffer is no longer being used as it may free memory from it.

Py\_ssize\_t **PyBuffer\_SizeFromFormat** (const char \*)

Return the implied *itemsize* from the struct-type *format*.

int **PyBuffer\_IsContiguous** (Py\_buffer \*view, char *fortran*)

Return 1 if the memory defined by the *view* is C-style (*fortran* is ‘C’) or Fortran-style (*fortran* is ‘F’) contiguous or either one (*fortran* is ‘A’). Return 0 otherwise.

void **PyBuffer\_FillContiguousStrides** (int *ndim*, Py\_ssize\_t *\*shape*, Py\_ssize\_t *\*strides*, Py\_ssize\_t *itemsize*, char *fortran*)

Fill the *strides* array with byte-strides of a contiguous (C-style if *fortran* is 'C' or Fortran-style if *fortran* is 'F') array of the given shape with the given number of bytes per element.

int **PyBuffer\_FillInfo** (Py\_buffer *\*view*, PyObject *\*obj*, void *\*buf*, Py\_ssize\_t *len*, int *readonly*, int *in-flags*)

Fill in a buffer-info structure, *view*, correctly for an exporter that can only share a contiguous chunk of memory of “unsigned bytes” of the given length. Return 0 on success and -1 (with raising an error) on error.

## MemoryView objects

New in version 2.7. A `memoryview` object exposes the new C level buffer interface as a Python object which can then be passed around like any other object.

PyObject **PyMemoryView\_FromObject** (PyObject *\*obj*)

Create a memoryview object from an object that defines the new buffer interface.

PyObject **PyMemoryView\_FromBuffer** (Py\_buffer *\*view*)

Create a memoryview object wrapping the given buffer-info structure *view*. The memoryview object then owns the buffer, which means you shouldn't try to release it yourself: it will be released on deallocation of the memoryview object.

PyObject **PyMemoryView\_GetContiguous** (PyObject *\*obj*, int *buffertype*, char *order*)

Create a memoryview object to a contiguous chunk of memory (in either 'C' or 'F' ortran *order*) from an object that defines the buffer interface. If memory is contiguous, the memoryview object points to the original memory. Otherwise copy is made and the memoryview points to a new bytes object.

int **PyMemoryView\_Check** (PyObject *\*obj*)

Return true if the object *obj* is a memoryview object. It is not currently allowed to create subclasses of `memoryview`.

Py\_buffer **PyMemoryView\_GET\_BUFFER** (PyObject *\*obj*)

Return a pointer to the buffer-info structure wrapped by the given object. The object **must** be a memoryview instance; this macro doesn't check its type, you must do it yourself or you will risk crashes.

## Old-style buffer objects

More information on the old buffer interface is provided in the section *Buffer Object Structures*, under the description for `PyBufferProcs`.

A “buffer object” is defined in the `bufferobject.h` header (included by `Python.h`). These objects look very similar to string objects at the Python programming level: they support slicing, indexing, concatenation, and some other standard string operations. However, their data can come from one of two sources: from a block of memory, or from another object which exports the buffer interface.

Buffer objects are useful as a way to expose the data from another object's buffer interface to the Python programmer. They can also be used as a zero-copy slicing mechanism. Using their ability to reference a block of memory, it is possible to expose any data to the Python programmer quite easily. The memory could be a large, constant array in a C extension, it could be a raw block of memory for manipulation before passing to an operating system library, or it could be used to pass around structured data in its native, in-memory format.

### PyBufferObject

This subtype of `PyObject` represents a buffer object.

### PyTypeObject PyBuffer\_Type

The instance of `PyTypeObject` which represents the Python buffer type; it is the same object as `buffer` and `types.BufferType` in the Python layer. .

int **Py\_END\_OF\_BUFFER**

This constant may be passed as the *size* parameter to `PyBuffer_FromObject()` or `PyBuffer_FromReadWriteObject()`. It indicates that the new `PyBufferObject` should refer to *base* object from the specified *offset* to the end of its exported buffer. Using this enables the caller to avoid querying the *base* object for its length.

int **PyBuffer\_Check** (`PyObject *p`)

Return true if the argument has type `PyBuffer_Type`.

`PyObject*` **PyBuffer\_FromObject** (`PyObject *base`, `Py_ssize_t offset`, `Py_ssize_t size`)

*Return value:* New reference.

Return a new read-only buffer object. This raises `TypeError` if *base* doesn't support the read-only buffer protocol or doesn't provide exactly one buffer segment, or it raises `ValueError` if *offset* is less than zero. The buffer will hold a reference to the *base* object, and the buffer's contents will refer to the *base* object's buffer interface, starting as position *offset* and extending for *size* bytes. If *size* is `Py_END_OF_BUFFER`, then the new buffer's contents extend to the length of the *base* object's exported buffer data. Changed in version 2.5: This function used an `int` type for *offset* and *size*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject*` **PyBuffer\_FromReadWriteObject** (`PyObject *base`, `Py_ssize_t offset`, `Py_ssize_t size`)

*Return value:* New reference.

Return a new writable buffer object. Parameters and exceptions are similar to those for `PyBuffer_FromObject()`. If the *base* object does not export the writeable buffer protocol, then `TypeError` is raised. Changed in version 2.5: This function used an `int` type for *offset* and *size*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject*` **PyBuffer\_FromMemory** (`void *ptr`, `Py_ssize_t size`)

*Return value:* New reference.

Return a new read-only buffer object that reads from a specified location in memory, with a specified size. The caller is responsible for ensuring that the memory buffer, passed in as *ptr*, is not deallocated while the returned buffer object exists. Raises `ValueError` if *size* is less than zero. Note that `Py_END_OF_BUFFER` may *not* be passed for the *size* parameter; `ValueError` will be raised in that case. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject*` **PyBuffer\_FromReadWriteMemory** (`void *ptr`, `Py_ssize_t size`)

*Return value:* New reference.

Similar to `PyBuffer_FromMemory()`, but the returned buffer is writable. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

`PyObject*` **PyBuffer\_New** (`Py_ssize_t size`)

*Return value:* New reference.

Return a new writable buffer object that maintains its own memory buffer of *size* bytes. `ValueError` is returned if *size* is not zero or positive. Note that the memory buffer (as returned by `PyObject_AsWriteBuffer()`) is not specifically aligned. Changed in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

## 7.3.5 Tuple Objects

### `PyTupleObject`

This subtype of `PyObject` represents a Python tuple object.

### `PyTypeObject PyTuple_Type`

This instance of `PyTypeObject` represents the Python tuple type; it is the same object as `tuple` and `types.TupleType` in the Python layer..

int **PyTuple\_Check** (PyObject \*p)

Return true if *p* is a tuple object or an instance of a subtype of the tuple type. Changed in version 2.2: Allowed subtypes to be accepted.

int **PyTuple\_CheckExact** (PyObject \*p)

Return true if *p* is a tuple object, but not an instance of a subtype of the tuple type. New in version 2.2.

PyObject\* **PyTuple\_New** (Py\_ssize\_t len)

*Return value:* New reference.

Return a new tuple object of size *len*, or *NULL* on failure. Changed in version 2.5: This function used an `int` type for *len*. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyTuple\_Pack** (Py\_ssize\_t n, ...)

*Return value:* New reference.

Return a new tuple object of size *n*, or *NULL* on failure. The tuple values are initialized to the subsequent *n* C arguments pointing to Python objects. `PyTuple_Pack(2, a, b)` is equivalent to `Py_BuildValue("(OO)", a, b)`. New in version 2.4. Changed in version 2.5: This function used an `int` type for *n*. This might require changes in your code for properly supporting 64-bit systems.

Py\_ssize\_t **PyTuple\_Size** (PyObject \*p)

Take a pointer to a tuple object, and return the size of that tuple. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

Py\_ssize\_t **PyTuple\_GET\_SIZE** (PyObject \*p)

Return the size of the tuple *p*, which must be non-*NULL* and point to a tuple; no error checking is performed. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyTuple\_GetItem** (PyObject \*p, Py\_ssize\_t pos)

*Return value:* Borrowed reference.

Return the object at position *pos* in the tuple pointed to by *p*. If *pos* is out of bounds, return *NULL* and sets an `IndexError` exception. Changed in version 2.5: This function used an `int` type for *pos*. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyTuple\_GET\_ITEM** (PyObject \*p, Py\_ssize\_t pos)

*Return value:* Borrowed reference.

Like `PyTuple_GetItem()`, but does no checking of its arguments. Changed in version 2.5: This function used an `int` type for *pos*. This might require changes in your code for properly supporting 64-bit systems.

PyObject\* **PyTuple\_GetSlice** (PyObject \*p, Py\_ssize\_t low, Py\_ssize\_t high)

*Return value:* New reference.

Take a slice of the tuple pointed to by *p* from *low* to *high* and return it as a new tuple. Changed in version 2.5: This function used an `int` type for *low* and *high*. This might require changes in your code for properly supporting 64-bit systems.

int **PyTuple\_SetItem** (PyObject \*p, Py\_ssize\_t pos, PyObject \*o)

Insert a reference to object *o* at position *pos* of the tuple pointed to by *p*. Return 0 on success.

---

**Note:** This function “steals” a reference to *o*.

---

Changed in version 2.5: This function used an `int` type for *pos*. This might require changes in your code for properly supporting 64-bit systems.

void **PyTuple\_SET\_ITEM** (PyObject \*p, Py\_ssize\_t pos, PyObject \*o)

Like `PyTuple_SetItem()`, but does no error checking, and should *only* be used to fill in brand new tuples.

---

**Note:** This function “steals” a reference to *o*.

---

Changed in version 2.5: This function used an `int` type for `pos`. This might require changes in your code for properly supporting 64-bit systems.

`int PyTuple_Resize (PyObject **p, Py_ssize_t newsize)`

Can be used to resize a tuple. `newsize` will be the new length of the tuple. Because tuples are *supposed* to be immutable, this should only be used if there is only one reference to the object. Do *not* use this if the tuple may already be known to some other part of the code. The tuple will always grow or shrink at the end. Think of this as destroying the old tuple and creating a new one, only more efficiently. Returns 0 on success. Client code should never assume that the resulting value of `*p` will be the same as before calling this function. If the object referenced by `*p` is replaced, the original `*p` is destroyed. On failure, returns `-1` and sets `*p` to `NULL`, and raises `MemoryError` or `SystemError`. Changed in version 2.2: Removed unused third parameter, `last_is_sticky`. Changed in version 2.5: This function used an `int` type for `newsize`. This might require changes in your code for properly supporting 64-bit systems.

`int PyTuple_ClearFreeList ()`

Clear the free list. Return the total number of freed items. New in version 2.6.

### 7.3.6 List Objects

#### `PyListObject`

This subtype of `PyObject` represents a Python list object.

#### `PyTypeObject PyList_Type`

This instance of `PyTypeObject` represents the Python list type. This is the same object as `list` in the Python layer.

`int PyList_Check (PyObject *p)`

Return true if `p` is a list object or an instance of a subtype of the list type. Changed in version 2.2: Allowed subtypes to be accepted.

`int PyList_CheckExact (PyObject *p)`

Return true if `p` is a list object, but not an instance of a subtype of the list type. New in version 2.2.

`PyObject* PyList_New (Py_ssize_t len)`

*Return value: New reference.*

Return a new list of length `len` on success, or `NULL` on failure.

---

**Note:** If `len` is greater than zero, the returned list object's items are set to `NULL`. Thus you cannot use abstract API functions such as `PySequence_SetItem()` or expose the object to Python code before setting all items to a real object with `PyList_SetItem()`.

---

Changed in version 2.5: This function used an `int` for `size`. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PyList_Size (PyObject *list)`

Return the length of the list object in `list`; this is equivalent to `len(list)` on a list object. Changed in version 2.5: This function returned an `int`. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PyList_GET_SIZE (PyObject *list)`

Macro form of `PyList_Size()` without error checking. Changed in version 2.5: This macro returned an `int`. This might require changes in your code for properly supporting 64-bit systems.

`PyObject* PyList_GetItem (PyObject *list, Py_ssize_t index)`

*Return value: Borrowed reference.*

Return the object at position `index` in the list pointed to by `list`. The position must be positive, indexing from the end of the list is not supported. If `index` is out of bounds, return `NULL` and set an `IndexError` exception.

Changed in version 2.5: This function used an `int` for `index`. This might require changes in your code for properly supporting 64-bit systems.

`PyObject*` **PyList\_GET\_ITEM** (`PyObject` \*list, `Py_ssize_t` i)

*Return value:* Borrowed reference.

Macro form of `PyList_GetItem()` without error checking. Changed in version 2.5: This macro used an `int` for `i`. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyList\_SetItem** (`PyObject` \*list, `Py_ssize_t` index, `PyObject` \*item)

Set the item at index `index` in list to `item`. Return 0 on success or `-1` on failure.

---

**Note:** This function “steals” a reference to `item` and discards a reference to an item already in the list at the affected position.

---

Changed in version 2.5: This function used an `int` for `index`. This might require changes in your code for properly supporting 64-bit systems.

`void` **PyList\_SET\_ITEM** (`PyObject` \*list, `Py_ssize_t` i, `PyObject` \*o)

Macro form of `PyList_SetItem()` without error checking. This is normally only used to fill in new lists where there is no previous content.

---

**Note:** This macro “steals” a reference to `item`, and, unlike `PyList_SetItem()`, does *not* discard a reference to any item that it being replaced; any reference in `list` at position `i` will be leaked.

---

Changed in version 2.5: This macro used an `int` for `i`. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyList\_Insert** (`PyObject` \*list, `Py_ssize_t` index, `PyObject` \*item)

Insert the item `item` into list `list` in front of index `index`. Return 0 if successful; return `-1` and set an exception if unsuccessful. Analogous to `list.insert(index, item)`. Changed in version 2.5: This function used an `int` for `index`. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyList\_Append** (`PyObject` \*list, `PyObject` \*item)

Append the object `item` at the end of list `list`. Return 0 if successful; return `-1` and set an exception if unsuccessful. Analogous to `list.append(item)`.

`PyObject*` **PyList\_GetSlice** (`PyObject` \*list, `Py_ssize_t` low, `Py_ssize_t` high)

*Return value:* New reference.

Return a list of the objects in `list` containing the objects *between* `low` and `high`. Return `NULL` and set an exception if unsuccessful. Analogous to `list[low:high]`. Negative indices, as when slicing from Python, are not supported. Changed in version 2.5: This function used an `int` for `low` and `high`. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyList\_SetSlice** (`PyObject` \*list, `Py_ssize_t` low, `Py_ssize_t` high, `PyObject` \*itemlist)

Set the slice of `list` between `low` and `high` to the contents of `itemlist`. Analogous to `list[low:high] = itemlist`. The `itemlist` may be `NULL`, indicating the assignment of an empty list (slice deletion). Return 0 on success, `-1` on failure. Negative indices, as when slicing from Python, are not supported. Changed in version 2.5: This function used an `int` for `low` and `high`. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyList\_Sort** (`PyObject` \*list)

Sort the items of `list` in place. Return 0 on success, `-1` on failure. This is equivalent to `list.sort()`.

`int` **PyList\_Reverse** (`PyObject` \*list)

Reverse the items of `list` in place. Return 0 on success, `-1` on failure. This is the equivalent of `list.reverse()`.

`PyObject*` **PyList\_AsTuple** (`PyObject *list`)

*Return value:* New reference.

Return a new tuple object containing the contents of `list`; equivalent to `tuple(list)`.

## 7.4 Mapping Objects

### 7.4.1 Dictionary Objects

**PyDictObject**

This subtype of `PyObject` represents a Python dictionary object.

`PyTypeObject` **PyDict\_Type**

This instance of `PyTypeObject` represents the Python dictionary type. This is exposed to Python programs as `dict` and `types.DictType`.

`int` **PyDict\_Check** (`PyObject *p`)

Return true if `p` is a dict object or an instance of a subtype of the dict type. Changed in version 2.2: Allowed subtypes to be accepted.

`int` **PyDict\_CheckExact** (`PyObject *p`)

Return true if `p` is a dict object, but not an instance of a subtype of the dict type. New in version 2.4.

`PyObject*` **PyDict\_New** ()

*Return value:* New reference.

Return a new empty dictionary, or `NULL` on failure.

`PyObject*` **PyDictProxy\_New** (`PyObject *dict`)

*Return value:* New reference.

Return a proxy object for a mapping which enforces read-only behavior. This is normally used to create a proxy to prevent modification of the dictionary for non-dynamic class types. New in version 2.2.

`void` **PyDict\_Clear** (`PyObject *p`)

Empty an existing dictionary of all key-value pairs.

`int` **PyDict\_Contains** (`PyObject *p`, `PyObject *key`)

Determine if dictionary `p` contains `key`. If an item in `p` matches `key`, return 1, otherwise return 0. On error, return -1. This is equivalent to the Python expression `key in p`. New in version 2.4.

`PyObject*` **PyDict\_Copy** (`PyObject *p`)

*Return value:* New reference.

Return a new dictionary that contains the same key-value pairs as `p`. New in version 1.6.

`int` **PyDict\_SetItem** (`PyObject *p`, `PyObject *key`, `PyObject *val`)

Insert `value` into the dictionary `p` with a key of `key`. `key` must be *hashable*; if it isn't, `TypeError` will be raised. Return 0 on success or -1 on failure.

`int` **PyDict\_SetItemString** (`PyObject *p`, `const char *key`, `PyObject *val`)

Insert `value` into the dictionary `p` using `key` as a key. `key` should be a `char*`. The key object is created using `PyString_FromString(key)`. Return 0 on success or -1 on failure.

`int` **PyDict\_DelItem** (`PyObject *p`, `PyObject *key`)

Remove the entry in dictionary `p` with key `key`. `key` must be hashable; if it isn't, `TypeError` is raised. Return 0 on success or -1 on failure.

`int` **PyDict\_DelItemString** (`PyObject *p`, `char *key`)

Remove the entry in dictionary `p` which has a key specified by the string `key`. Return 0 on success or -1 on failure.

`PyObject*` **PyDict\_GetItem** (`PyObject *p`, `PyObject *key`)

*Return value: Borrowed reference.*

Return the object from dictionary `p` which has a key `key`. Return `NULL` if the key `key` is not present, but *without* setting an exception.

`PyObject*` **PyDict\_GetItemString** (`PyObject *p`, `const char *key`)

*Return value: Borrowed reference.*

This is the same as `PyDict_GetItem()`, but `key` is specified as a `char*`, rather than a `PyObject*`.

`PyObject*` **PyDict\_Items** (`PyObject *p`)

*Return value: New reference.*

Return a `PyListObject` containing all the items from the dictionary, as in the dictionary method `dict.items()`.

`PyObject*` **PyDict\_Keys** (`PyObject *p`)

*Return value: New reference.*

Return a `PyListObject` containing all the keys from the dictionary, as in the dictionary method `dict.keys()`.

`PyObject*` **PyDict\_Values** (`PyObject *p`)

*Return value: New reference.*

Return a `PyListObject` containing all the values from the dictionary `p`, as in the dictionary method `dict.values()`.

`Py_ssize_t` **PyDict\_Size** (`PyObject *p`)

Return the number of items in the dictionary. This is equivalent to `len(p)` on a dictionary. Changed in version 2.5: This function returned an `int` type. This might require changes in your code for properly supporting 64-bit systems.

`int` **PyDict\_Next** (`PyObject *p`, `Py_ssize_t *ppos`, `PyObject **pkey`, `PyObject **pvalue`)

Iterate over all key-value pairs in the dictionary `p`. The `Py_ssize_t` referred to by `ppos` must be initialized to 0 prior to the first call to this function to start the iteration; the function returns true for each pair in the dictionary, and false once all pairs have been reported. The parameters `pkey` and `pvalue` should either point to `PyObject*` variables that will be filled in with each key and value, respectively, or may be `NULL`. Any references returned through them are borrowed. `ppos` should not be altered during iteration. Its value represents offsets within the internal dictionary structure, and since the structure is sparse, the offsets are not consecutive.

For example:

```
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value)) {
    /* do something interesting with the values... */
    ...
}
```

The dictionary `p` should not be mutated during iteration. It is safe (since Python 2.1) to modify the values of the keys as you iterate over the dictionary, but only so long as the set of keys does not change. For example:

```
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value)) {
    int i = PyInt_AS_LONG(value) + 1;
    PyObject *o = PyInt_FromLong(i);
    if (o == NULL)
```

```
        return -1;
    if (PyDict_SetItem(self->dict, key, o) < 0) {
        Py_DECREF(o);
        return -1;
    }
    Py_DECREF(o);
}
```

Changed in version 2.5: This function used an `int *` type for `ppos`. This might require changes in your code for properly supporting 64-bit systems.

int **PyDict\_Merge** (PyObject \*a, PyObject \*b, int *override*)

Iterate over mapping object *b* adding key-value pairs to dictionary *a*. *b* may be a dictionary, or any object supporting `PyMapping_Keys()` and `PyObject_GetItem()`. If *override* is true, existing pairs in *a* will be replaced if a matching key is found in *b*, otherwise pairs will only be added if there is not a matching key in *a*. Return 0 on success or -1 if an exception was raised. New in version 2.2.

int **PyDict\_Update** (PyObject \*a, PyObject \*b)

This is the same as `PyDict_Merge(a, b, 1)` in C, or `a.update(b)` in Python. Return 0 on success or -1 if an exception was raised. New in version 2.2.

int **PyDict\_MergeFromSeq2** (PyObject \*a, PyObject \*seq2, int *override*)

Update or merge into dictionary *a*, from the key-value pairs in *seq2*. *seq2* must be an iterable object producing iterable objects of length 2, viewed as key-value pairs. In case of duplicate keys, the last wins if *override* is true, else the first wins. Return 0 on success or -1 if an exception was raised. Equivalent Python (except for the return value):

```
def PyDict_MergeFromSeq2(a, seq2, override):
    for key, value in seq2:
        if override or key not in a:
            a[key] = value
```

New in version 2.2.

## 7.5 Other Objects

### 7.5.1 Class and Instance Objects

Note that the class objects described here represent old-style classes, which will go away in Python 3. When creating new types for extension modules, you will want to work with type objects (section [Type Objects](#)).

#### **PyClassObject**

The C structure of the objects used to describe built-in classes.

#### **PyObject\* PyClass\_Type**

This is the type object for class objects; it is the same object as `types.ClassType` in the Python layer.

int **PyClass\_Check** (PyObject \*o)

Return true if the object *o* is a class object, including instances of types derived from the standard class object. Return false in all other cases.

int **PyClass\_IsSubclass** (PyObject \*klass, PyObject \*base)

Return true if *klass* is a subclass of *base*. Return false in all other cases.

There are very few functions specific to instance objects.

**PyObject PyInstance\_Type**

Type object for class instances.

**int PyInstance\_Check (PyObject \*obj)**

Return true if *obj* is an instance.

**PyObject\* PyInstance\_New (PyObject \*class, PyObject \*arg, PyObject \*kw)**

*Return value:* New reference.

Create a new instance of a specific class. The parameters *arg* and *kw* are used as the positional and keyword parameters to the object's constructor.

**PyObject\* PyInstance\_NewRaw (PyObject \*class, PyObject \*dict)**

*Return value:* New reference.

Create a new instance of a specific class without calling its constructor. *class* is the class of new object. The *dict* parameter will be used as the object's `__dict__`; if *NULL*, a new dictionary will be created for the instance.

## 7.5.2 Function Objects

There are a few functions specific to Python functions.

**PyFunctionObject**

The C structure used for functions.

**PyObject PyFunction\_Type**

This is an instance of `PyObject` and represents the Python function type. It is exposed to Python programmers as `types.FunctionType`.

**int PyFunction\_Check (PyObject \*o)**

Return true if *o* is a function object (has type `PyFunction_Type`). The parameter must not be *NULL*.

**PyObject\* PyFunction\_New (PyObject \*code, PyObject \*globals)**

*Return value:* New reference.

Return a new function object associated with the code object *code*. *globals* must be a dictionary with the global variables accessible to the function.

The function's docstring, name and `__module__` are retrieved from the code object, the argument defaults and closure are set to *NULL*.

**PyObject\* PyFunction\_GetCode (PyObject \*op)**

*Return value:* Borrowed reference.

Return the code object associated with the function object *op*.

**PyObject\* PyFunction\_GetGlobals (PyObject \*op)**

*Return value:* Borrowed reference.

Return the globals dictionary associated with the function object *op*.

**PyObject\* PyFunction\_GetModule (PyObject \*op)**

*Return value:* Borrowed reference.

Return the `__module__` attribute of the function object *op*. This is normally a string containing the module name, but can be set to any other object by Python code.

**PyObject\* PyFunction\_GetDefaults (PyObject \*op)**

*Return value:* Borrowed reference.

Return the argument default values of the function object *op*. This can be a tuple of arguments or *NULL*.

**int PyFunction\_SetDefaults (PyObject \*op, PyObject \*defaults)**

Set the argument default values for the function object *op*. *defaults* must be *Py\_None* or a tuple.

Raises `SystemError` and returns `-1` on failure.

**PyObject\*** **PyFunction\_GetClosure** (PyObject \*op)

*Return value: Borrowed reference.*

Return the closure associated with the function object *op*. This can be *NULL* or a tuple of cell objects.

**int** **PyFunction\_SetClosure** (PyObject \*op, PyObject \*closure)

Set the closure associated with the function object *op*. *closure* must be *Py\_None* or a tuple of cell objects.

Raises *SystemError* and returns *-1* on failure.

### 7.5.3 Method Objects

There are some useful functions that are useful for working with method objects.

**PyObject** **PyMethod\_Type**

This instance of **PyObject** represents the Python method type. This is exposed to Python programs as `types.MethodType`.

**int** **PyMethod\_Check** (PyObject \*o)

Return true if *o* is a method object (has type **PyMethod\_Type**). The parameter must not be *NULL*.

**PyObject\*** **PyMethod\_New** (PyObject \*func, PyObject \*self, PyObject \*class)

*Return value: New reference.*

Return a new method object, with *func* being any callable object; this is the function that will be called when the method is called. If this method should be bound to an instance, *self* should be the instance and *class* should be the class of *self*, otherwise *self* should be *NULL* and *class* should be the class which provides the unbound method..

**PyObject\*** **PyMethod\_Class** (PyObject \*meth)

*Return value: Borrowed reference.*

Return the class object from which the method *meth* was created; if this was created from an instance, it will be the class of the instance.

**PyObject\*** **PyMethod\_GET\_CLASS** (PyObject \*meth)

*Return value: Borrowed reference.*

Macro version of **PyMethod\_Class** () which avoids error checking.

**PyObject\*** **PyMethod\_Function** (PyObject \*meth)

*Return value: Borrowed reference.*

Return the function object associated with the method *meth*.

**PyObject\*** **PyMethod\_GET\_FUNCTION** (PyObject \*meth)

*Return value: Borrowed reference.*

Macro version of **PyMethod\_Function** () which avoids error checking.

**PyObject\*** **PyMethod\_Self** (PyObject \*meth)

*Return value: Borrowed reference.*

Return the instance associated with the method *meth* if it is bound, otherwise return *NULL*.

**PyObject\*** **PyMethod\_GET\_SELF** (PyObject \*meth)

*Return value: Borrowed reference.*

Macro version of **PyMethod\_Self** () which avoids error checking.

**int** **PyMethod\_ClearFreeList** ()

Clear the free list. Return the total number of freed items. New in version 2.6.

## 7.5.4 File Objects

Python's built-in file objects are implemented entirely on the `FILE*` support from the C standard library. This is an implementation detail and may change in future releases of Python.

### `PyFileObject`

This subtype of `PyObject` represents a Python file object.

### `PyTypeObject PyFile_Type`

This instance of `PyTypeObject` represents the Python file type. This is exposed to Python programs as `file` and `types.FileType`.

### `int PyFile_Check (PyObject *p)`

Return true if its argument is a `PyFileObject` or a subtype of `PyFileObject`. Changed in version 2.2: Allowed subtypes to be accepted.

### `int PyFile_CheckExact (PyObject *p)`

Return true if its argument is a `PyFileObject`, but not a subtype of `PyFileObject`. New in version 2.2.

### `PyObject* PyFile_FromString (char *filename, char *mode)`

*Return value:* New reference.

On success, return a new file object that is opened on the file given by `filename`, with a file mode given by `mode`, where `mode` has the same semantics as the standard C routine `fopen()`. On failure, return `NULL`.

### `PyObject* PyFile_FromFile (FILE *fp, char *name, char *mode, int (*close)(FILE*))`

*Return value:* New reference.

Create a new `PyFileObject` from the already-open standard C file pointer, `fp`. The function `close` will be called when the file should be closed. Return `NULL` and close the file using `close` on failure. `close` is optional and can be set to `NULL`.

### `FILE* PyFile_AsFile (PyObject *p)`

Return the file object associated with `p` as a `FILE*`.

If the caller will ever use the returned `FILE*` object while the `GIL` is released it must also call the `PyFile_IncUseCount()` and `PyFile_DecUseCount()` functions described below as appropriate.

### `void PyFile_IncUseCount (PyFileObject *p)`

Increments the `PyFileObject`'s internal use count to indicate that the underlying `FILE*` is being used. This prevents Python from calling `f_close()` on it from another thread. Callers of this must call `PyFile_DecUseCount()` when they are finished with the `FILE*`. Otherwise the file object will never be closed by Python.

The `GIL` must be held while calling this function.

The suggested use is to call this after `PyFile_AsFile()` and before you release the `GIL`:

```
FILE *fp = PyFile_AsFile(p);
PyFile_IncUseCount(p);
/* ... */
Py_BEGIN_ALLOW_THREADS
do_something(fp);
Py_END_ALLOW_THREADS
/* ... */
PyFile_DecUseCount(p);
```

New in version 2.6.

### `void PyFile_DecUseCount (PyFileObject *p)`

Decrements the `PyFileObject`'s internal `unlocked_count` member to indicate that the caller is done with its own use of the `FILE*`. This may only be called to undo a prior call to `PyFile_IncUseCount()`.

The *GIL* must be held while calling this function (see the example above). New in version 2.6.

**PyObject\*** **PyFile\_GetLine** (PyObject \**p*, int *n*)

*Return value:* New reference.

Equivalent to `p.readline([n])`, this function reads one line from the object *p*. *p* may be a file object or any object with a `readline()` method. If *n* is 0, exactly one line is read, regardless of the length of the line. If *n* is greater than 0, no more than *n* bytes will be read from the file; a partial line can be returned. In both cases, an empty string is returned if the end of the file is reached immediately. If *n* is less than 0, however, one line is read regardless of length, but `EOFError` is raised if the end of the file is reached immediately.

**PyObject\*** **PyFile\_Name** (PyObject \**p*)

*Return value:* Borrowed reference.

Return the name of the file specified by *p* as a string object.

void **PyFile\_SetBufSize** (PyFileObject \**p*, int *n*)

Available on systems with `setvbuf()` only. This should only be called immediately after file object creation.

int **PyFile\_SetEncoding** (PyFileObject \**p*, const char \**enc*)

Set the file's encoding for Unicode output to *enc*. Return 1 on success and 0 on failure. New in version 2.3.

int **PyFile\_SetEncodingAndErrors** (PyFileObject \**p*, const char \**enc*, \**errors*)

Set the file's encoding for Unicode output to *enc*, and its error mode to *err*. Return 1 on success and 0 on failure. New in version 2.6.

int **PyFile\_SoftSpace** (PyObject \**p*, int *newflag*)

This function exists for internal use by the interpreter. Set the `softspace` attribute of *p* to *newflag* and return the previous value. *p* does not have to be a file object for this function to work properly; any object is supported (though its only interesting if the `softspace` attribute can be set). This function clears any errors, and will return 0 as the previous value if the attribute either does not exist or if there were errors in retrieving it. There is no way to detect errors from this function, but doing so should not be needed.

int **PyFile\_WriteObject** (PyObject \**obj*, PyObject \**p*, int *flags*)

Write object *obj* to file object *p*. The only supported flag for *flags* is `Py_PRINT_RAW`; if given, the `str()` of the object is written instead of the `repr()`. Return 0 on success or -1 on failure; the appropriate exception will be set.

int **PyFile\_WriteString** (const char \**s*, PyObject \**p*)

Write string *s* to file object *p*. Return 0 on success or -1 on failure; the appropriate exception will be set.

## 7.5.5 Module Objects

There are only a few functions special to module objects.

**PyTypeObject** **PyModule\_Type**

This instance of `PyTypeObject` represents the Python module type. This is exposed to Python programs as `types.ModuleType`.

int **PyModule\_Check** (PyObject \**p*)

Return true if *p* is a module object, or a subtype of a module object. Changed in version 2.2: Allowed subtypes to be accepted.

int **PyModule\_CheckExact** (PyObject \**p*)

Return true if *p* is a module object, but not a subtype of `PyModule_Type`. New in version 2.2.

**PyObject\*** **PyModule\_New** (const char \**name*)

*Return value:* New reference.

Return a new module object with the `__name__` attribute set to *name*. Only the module's `__doc__` and `__name__` attributes are filled in; the caller is responsible for providing a `__file__` attribute.

**PyObject\*** **PyModule\_GetDict** (PyObject \**module*)

*Return value:* Borrowed reference.

Return the dictionary object that implements *module*'s namespace; this object is the same as the `__dict__` attribute of the module object. This function never fails. It is recommended extensions use other `PyModule_*()` and `PyObject_*()` functions rather than directly manipulate a module's `__dict__`.

**char\*** **PyModule\_GetName** (PyObject \**module*)

Return *module*'s `__name__` value. If the module does not provide one, or if it is not a string, `SystemError` is raised and `NULL` is returned.

**char\*** **PyModule\_GetFilename** (PyObject \**module*)

Return the name of the file from which *module* was loaded using *module*'s `__file__` attribute. If this is not defined, or if it is not a string, raise `SystemError` and return `NULL`.

**int** **PyModule\_AddObject** (PyObject \**module*, const char \**name*, PyObject \**value*)

Add an object to *module* as *name*. This is a convenience function which can be used from the module's initialization function. This steals a reference to *value*. Return `-1` on error, `0` on success. New in version 2.0.

**int** **PyModule\_AddIntConstant** (PyObject \**module*, const char \**name*, long *value*)

Add an integer constant to *module* as *name*. This convenience function can be used from the module's initialization function. Return `-1` on error, `0` on success. New in version 2.0.

**int** **PyModule\_AddStringConstant** (PyObject \**module*, const char \**name*, const char \**value*)

Add a string constant to *module* as *name*. This convenience function can be used from the module's initialization function. The string *value* must be null-terminated. Return `-1` on error, `0` on success. New in version 2.0.

**int** **PyModule\_AddIntMacro** (PyObject \**module*, macro)

Add an int constant to *module*. The name and the value are taken from *macro*. For example `PyModule_AddIntMacro(module, AF_INET)` adds the int constant `AF_INET` with the value of `AF_INET` to *module*. Return `-1` on error, `0` on success. New in version 2.6.

**int** **PyModule\_AddStringMacro** (PyObject \**module*, macro)

Add a string constant to *module*.

New in version 2.6.

## 7.5.6 Iterator Objects

Python provides two general-purpose iterator objects. The first, a sequence iterator, works with an arbitrary sequence supporting the `__getitem__()` method. The second works with a callable object and a sentinel value, calling the callable for each item in the sequence, and ending the iteration when the sentinel value is returned.

**PyTypeObject** **PySeqIter\_Type**

Type object for iterator objects returned by `PySeqIter_New()` and the one-argument form of the `iter()` built-in function for built-in sequence types. New in version 2.2.

**int** **PySeqIter\_Check** (*op*)

Return true if the type of *op* is `PySeqIter_Type`. New in version 2.2.

**PyObject\*** **PySeqIter\_New** (PyObject \**seq*)

*Return value:* New reference.

Return an iterator that works with a general sequence object, *seq*. The iteration ends when the sequence raises `IndexError` for the subscripting operation. New in version 2.2.

**PyTypeObject** **PyCallIter\_Type**

Type object for iterator objects returned by `PyCallIter_New()` and the two-argument form of the `iter()` built-in function. New in version 2.2.

int **PyCallIter\_Check** (op)

Return true if the type of *op* is `PyCallIter_Type`. New in version 2.2.

`PyObject*` **PyCallIter\_New** (`PyObject *`*callable*, `PyObject *`*sentinel*)

*Return value:* New reference.

Return a new iterator. The first parameter, *callable*, can be any Python callable object that can be called with no parameters; each call to it should return the next item in the iteration. When *callable* returns a value equal to *sentinel*, the iteration will be terminated. New in version 2.2.

## 7.5.7 Descriptor Objects

“Descriptors” are objects that describe some attribute of an object. They are found in the dictionary of type objects.

`PyTypeObject` **PyProperty\_Type**

The type object for the built-in descriptor types. New in version 2.2.

`PyObject*` **PyDescr\_NewGetSet** (`PyTypeObject *`*type*, struct `PyGetSetDef *`*getset*)

*Return value:* New reference.

New in version 2.2.

`PyObject*` **PyDescr\_NewMember** (`PyTypeObject *`*type*, struct `PyMemberDef *`*meth*)

*Return value:* New reference.

New in version 2.2.

`PyObject*` **PyDescr\_NewMethod** (`PyTypeObject *`*type*, struct `PyMethodDef *`*meth*)

*Return value:* New reference.

New in version 2.2.

`PyObject*` **PyDescr\_NewWrapper** (`PyTypeObject *`*type*, struct `wrapperbase *`*wrapper*, void *\*wrapped*)

*Return value:* New reference.

New in version 2.2.

`PyObject*` **PyDescr\_NewClassMethod** (`PyTypeObject *`*type*, `PyMethodDef *`*method*)

*Return value:* New reference.

New in version 2.3.

int **PyDescr\_IsData** (`PyObject *`*descr*)

Return true if the descriptor objects *descr* describes a data attribute, or false if it describes a method. *descr* must be a descriptor object; there is no error checking. New in version 2.2.

`PyObject*` **PyWrapper\_New** (`PyObject *`*obj*, `PyObject *`*obj2*)

*Return value:* New reference.

New in version 2.2.

## 7.5.8 Slice Objects

`PyTypeObject` **PySlice\_Type**

The type object for slice objects. This is the same as `slice` and `types.SliceType`.

int **PySlice\_Check** (`PyObject *`*ob*)

Return true if *ob* is a slice object; *ob* must not be `NULL`.

`PyObject*` **PySlice\_New** (`PyObject *`*start*, `PyObject *`*stop*, `PyObject *`*step*)

*Return value:* New reference.

Return a new slice object with the given values. The *start*, *stop*, and *step* parameters are used as the values of the slice object attributes of the same names. Any of the values may be `NULL`, in which case the `None` will be used for the corresponding attribute. Return `NULL` if the new object could not be allocated.

`int PySlice_GetIndices` (PySliceObject \**slice*, Py\_ssize\_t *length*, Py\_ssize\_t \**start*, Py\_ssize\_t \**stop*, Py\_ssize\_t \**step*)

Retrieve the start, stop and step indices from the slice object *slice*, assuming a sequence of length *length*. Treats indices greater than *length* as errors.

Returns 0 on success and -1 on error with no exception set (unless one of the indices was not None and failed to be converted to an integer, in which case -1 is returned with an exception set).

You probably do not want to use this function. If you want to use slice objects in versions of Python prior to 2.3, you would probably do well to incorporate the source of `PySlice_GetIndicesEx()`, suitably renamed, in the source of your extension. Changed in version 2.5: This function used an `int` type for *length* and an `int *` type for *start*, *stop*, and *step*. This might require changes in your code for properly supporting 64-bit systems.

`int PySlice_GetIndicesEx` (PySliceObject \**slice*, Py\_ssize\_t *length*, Py\_ssize\_t \**start*, Py\_ssize\_t \**stop*, Py\_ssize\_t \**step*, Py\_ssize\_t \**slicelength*)

Usable replacement for `PySlice_GetIndices()`. Retrieve the start, stop, and step indices from the slice object *slice* assuming a sequence of length *length*, and store the length of the slice in *slicelength*. Out of bounds indices are clipped in a manner consistent with the handling of normal slices.

Returns 0 on success and -1 on error with exception set. New in version 2.3. Changed in version 2.5: This function used an `int` type for *length* and an `int *` type for *start*, *stop*, *step*, and *slicelength*. This might require changes in your code for properly supporting 64-bit systems.

## 7.5.9 Weak Reference Objects

Python supports *weak references* as first-class objects. There are two specific object types which directly implement weak references. The first is a simple reference object, and the second acts as a proxy for the original object as much as it can.

`int PyWeakref_Check` (ob)

Return true if *ob* is either a reference or proxy object. New in version 2.2.

`int PyWeakref_CheckRef` (ob)

Return true if *ob* is a reference object. New in version 2.2.

`int PyWeakref_CheckProxy` (ob)

Return true if *ob* is a proxy object. New in version 2.2.

`PyObject* PyWeakref_NewRef` (PyObject \**ob*, PyObject \**callback*)

*Return value:* New reference.

Return a weak reference object for the object *ob*. This will always return a new reference, but is not guaranteed to create a new object; an existing reference object may be returned. The second parameter, *callback*, can be a callable object that receives notification when *ob* is garbage collected; it should accept a single parameter, which will be the weak reference object itself. *callback* may also be None or NULL. If *ob* is not a weakly-referencable object, or if *callback* is not callable, None, or NULL, this will return NULL and raise TypeError. New in version 2.2.

`PyObject* PyWeakref_NewProxy` (PyObject \**ob*, PyObject \**callback*)

*Return value:* New reference.

Return a weak reference proxy object for the object *ob*. This will always return a new reference, but is not guaranteed to create a new object; an existing proxy object may be returned. The second parameter, *callback*, can be a callable object that receives notification when *ob* is garbage collected; it should accept a single parameter, which will be the weak reference object itself. *callback* may also be None or NULL. If *ob* is not a weakly-referencable object, or if *callback* is not callable, None, or NULL, this will return NULL and raise TypeError. New in version 2.2.

`PyObject* PyWeakref_GetObject` (PyObject \**ref*)

*Return value:* Borrowed reference.

Return the referenced object from a weak reference, *ref*. If the referent is no longer live, returns `Py_None`. New in version 2.2.

**Warning:** This function returns a **borrowed reference** to the referenced object. This means that you should always call `Py_INCREF()` on the object except if you know that it cannot be destroyed while you are still using it.

`PyObject*` **PyWeakref\_GET\_OBJECT** (`PyObject *`*ref*)

Return value: Borrowed reference.

Similar to `PyWeakref_GetObject()`, but implemented as a macro that does no error checking. New in version 2.2.

## 7.5.10 Capsules

Refer to *using-capsules* for more information on using these objects.

### PyCapsule

This subtype of `PyObject` represents an opaque value, useful for C extension modules who need to pass an opaque value (as a `void*` pointer) through Python code to other C code. It is often used to make a C function pointer defined in one module available to other modules, so the regular import mechanism can be used to access C APIs defined in dynamically loaded modules.

### PyCapsule\_Destructor

The type of a destructor callback for a capsule. Defined as:

```
typedef void (*PyCapsule_Destructor) (PyObject *);
```

See `PyCapsule_New()` for the semantics of `PyCapsule_Destructor` callbacks.

int **PyCapsule\_CheckExact** (`PyObject *`*p*)

Return true if its argument is a `PyCapsule`.

`PyObject*` **PyCapsule\_New** (`void *`*pointer*, `const char *`*name*, `PyCapsule_Destructor` *destructor*)

Return value: New reference.

Create a `PyCapsule` encapsulating the *pointer*. The *pointer* argument may not be `NULL`.

On failure, set an exception and return `NULL`.

The *name* string may either be `NULL` or a pointer to a valid C string. If non-`NULL`, this string must outlive the capsule. (Though it is permitted to free it inside the *destructor*.)

If the *destructor* argument is not `NULL`, it will be called with the capsule as its argument when it is destroyed.

If this capsule will be stored as an attribute of a module, the *name* should be specified as `modulename.attributename`. This will enable other modules to import the capsule using `PyCapsule_Import()`.

`void*` **PyCapsule\_GetPointer** (`PyObject *`*capsule*, `const char *`*name*)

Retrieve the *pointer* stored in the capsule. On failure, set an exception and return `NULL`.

The *name* parameter must compare exactly to the name stored in the capsule. If the name stored in the capsule is `NULL`, the *name* passed in must also be `NULL`. Python uses the C function `strcmp()` to compare capsule names.

`PyCapsule_Destructor` **PyCapsule\_GetDestructor** (`PyObject *`*capsule*)

Return the current destructor stored in the capsule. On failure, set an exception and return `NULL`.

It is legal for a capsule to have a `NULL` destructor. This makes a `NULL` return code somewhat ambiguous; use `PyCapsule_IsValid()` or `PyErr_Occurred()` to disambiguate.

`void* PyCapsule_GetContext (PyObject *capsule)`

Return the current context stored in the capsule. On failure, set an exception and return `NULL`.

It is legal for a capsule to have a `NULL` context. This makes a `NULL` return code somewhat ambiguous; use `PyCapsule_IsValid()` or `PyErr_Occurred()` to disambiguate.

`const char* PyCapsule_GetName (PyObject *capsule)`

Return the current name stored in the capsule. On failure, set an exception and return `NULL`.

It is legal for a capsule to have a `NULL` name. This makes a `NULL` return code somewhat ambiguous; use `PyCapsule_IsValid()` or `PyErr_Occurred()` to disambiguate.

`void* PyCapsule_Import (const char *name, int no_block)`

Import a pointer to a C object from a capsule attribute in a module. The `name` parameter should specify the full name to the attribute, as in `module.attribute`. The `name` stored in the capsule must match this string exactly. If `no_block` is true, import the module without blocking (using `PyImport_ImportModuleNoBlock()`). If `no_block` is false, import the module conventionally (using `PyImport_ImportModule()`).

Return the capsule's internal *pointer* on success. On failure, set an exception and return `NULL`. However, if `PyCapsule_Import()` failed to import the module, and `no_block` was true, no exception is set.

`int PyCapsule_IsValid (PyObject *capsule, const char *name)`

Determines whether or not `capsule` is a valid capsule. A valid capsule is non-`NULL`, passes `PyCapsule_CheckExact()`, has a non-`NULL` pointer stored in it, and its internal name matches the `name` parameter. (See `PyCapsule_GetPointer()` for information on how capsule names are compared.)

In other words, if `PyCapsule_IsValid()` returns a true value, calls to any of the accessors (any function starting with `PyCapsule_Get()`) are guaranteed to succeed.

Return a nonzero value if the object is valid and matches the name passed in. Return 0 otherwise. This function will not fail.

`int PyCapsule_SetContext (PyObject *capsule, void *context)`

Set the context pointer inside `capsule` to `context`.

Return 0 on success. Return nonzero and set an exception on failure.

`int PyCapsule_SetDestructor (PyObject *capsule, PyCapsule_Destructor destructor)`

Set the destructor inside `capsule` to `destructor`.

Return 0 on success. Return nonzero and set an exception on failure.

`int PyCapsule_SetName (PyObject *capsule, const char *name)`

Set the name inside `capsule` to `name`. If non-`NULL`, the name must outlive the capsule. If the previous `name` stored in the capsule was not `NULL`, no attempt is made to free it.

Return 0 on success. Return nonzero and set an exception on failure.

`int PyCapsule_SetPointer (PyObject *capsule, void *pointer)`

Set the void pointer inside `capsule` to `pointer`. The pointer may not be `NULL`.

Return 0 on success. Return nonzero and set an exception on failure.

## 7.5.11 CObjects

**Warning:** The CObject API is deprecated as of Python 2.7. Please switch to the new *Capsules* API.

### PyCObject

This subtype of `PyObject` represents an opaque value, useful for C extension modules who need to pass an

opaque value (as a `void*` pointer) through Python code to other C code. It is often used to make a C function pointer defined in one module available to other modules, so the regular import mechanism can be used to access C APIs defined in dynamically loaded modules.

int **PyObject\_Check** (PyObject \*p)

Return true if its argument is a `PyObject`.

PyObject\* **PyObject\_FromVoidPtr** (void\* cobj, void (\*destr)(void \*))

Return value: New reference.

Create a `PyObject` from the `void * cobj`. The `destr` function will be called when the object is reclaimed, unless it is `NULL`.

PyObject\* **PyObject\_FromVoidPtrAndDesc** (void\* cobj, void\* desc, void (\*destr)(void \*, void \*))

Return value: New reference.

Create a `PyObject` from the `void * cobj`. The `destr` function will be called when the object is reclaimed. The `desc` argument can be used to pass extra callback data for the destructor function.

void\* **PyObject\_AsVoidPtr** (PyObject\* self)

Return the object `void *` that the `PyObject self` was created with.

void\* **PyObject\_GetDesc** (PyObject\* self)

Return the description `void *` that the `PyObject self` was created with.

int **PyObject\_SetVoidPtr** (PyObject\* self, void\* cobj)

Set the void pointer inside `self` to `cobj`. The `PyObject` must not have an associated destructor. Return true on success, false on failure.

### 7.5.12 Cell Objects

“Cell” objects are used to implement variables referenced by multiple scopes. For each such variable, a cell object is created to store the value; the local variables of each stack frame that references the value contains a reference to the cells from outer scopes which also use that variable. When the value is accessed, the value contained in the cell is used instead of the cell object itself. This de-referencing of the cell object requires support from the generated byte-code; these are not automatically de-referenced when accessed. Cell objects are not likely to be useful elsewhere.

#### **PyCellObject**

The C structure used for cell objects.

#### **PyObject PyCell\_Type**

The type object corresponding to cell objects.

int **PyCell\_Check** (ob)

Return true if `ob` is a cell object; `ob` must not be `NULL`.

PyObject\* **PyCell\_New** (PyObject \*ob)

Return value: New reference.

Create and return a new cell object containing the value `ob`. The parameter may be `NULL`.

PyObject\* **PyCell\_Get** (PyObject \*cell)

Return value: New reference.

Return the contents of the cell `cell`.

PyObject\* **PyCell\_GET** (PyObject \*cell)

Return value: Borrowed reference.

Return the contents of the cell `cell`, but without checking that `cell` is non-`NULL` and a cell object.

int **PyCell\_Set** (PyObject \*cell, PyObject \*value)

Set the contents of the cell object `cell` to `value`. This releases the reference to any current content of the cell. `value` may be `NULL`. `cell` must be non-`NULL`; if it is not a cell object, `-1` will be returned. On success, `0` will be returned.

void **PyCell\_SET** (PyObject \*cell, PyObject \*value)

Sets the value of the cell object *cell* to *value*. No reference counts are adjusted, and no checks are made for safety; *cell* must be non-NULL and must be a cell object.

### 7.5.13 Generator Objects

Generator objects are what Python uses to implement generator iterators. They are normally created by iterating over a function that yields values, rather than explicitly calling `PyGen_New()`.

#### **PyGenObject**

The C structure used for generator objects.

#### **PyTypeObject PyGen\_Type**

The type object corresponding to generator objects

int **PyGen\_Check** (ob)

Return true if *ob* is a generator object; *ob* must not be NULL.

int **PyGen\_CheckExact** (ob)

Return true if *ob*'s type is `PyGen_Type` is a generator object; *ob* must not be NULL.

PyObject\* **PyGen\_New** (PyFrameObject \*frame)

Return value: New reference.

Create and return a new generator object based on the *frame* object. A reference to *frame* is stolen by this function. The parameter must not be NULL.

### 7.5.14 DateTime Objects

Various date and time objects are supplied by the `datetime` module. Before using any of these functions, the header file `datetime.h` must be included in your source (note that this is not included by `Python.h`), and the macro `PyDateTime_IMPORT` must be invoked, usually as part of the module initialisation function. The macro puts a pointer to a C structure into a static variable, `PyDateTimeAPI`, that is used by the following macros.

Type-check macros:

int **PyDate\_Check** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_DateType` or a subtype of `PyDateTime_DateType`. *ob* must not be NULL. New in version 2.4.

int **PyDate\_CheckExact** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_DateType`. *ob* must not be NULL. New in version 2.4.

int **PyDateTime\_Check** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_DateTimeType` or a subtype of `PyDateTime_DateTimeType`. *ob* must not be NULL. New in version 2.4.

int **PyDateTime\_CheckExact** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_DateTimeType`. *ob* must not be NULL. New in version 2.4.

int **PyTime\_Check** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_TimeType` or a subtype of `PyDateTime_TimeType`. *ob* must not be NULL. New in version 2.4.

int **PyTime\_CheckExact** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_TimeType`. *ob* must not be NULL. New in version 2.4.

int **PyDelta\_Check** (PyObject \*ob)

Return true if *ob* is of type `PyDateTime_DeltaType` or a subtype of `PyDateTime_DeltaType`. *ob* must not be NULL. New in version 2.4.

`int PyDelta_CheckExact (PyObject *ob)`

Return true if *ob* is of type `PyDateTime_DeltaType`. *ob* must not be `NULL`. New in version 2.4.

`int PyTZInfo_Check (PyObject *ob)`

Return true if *ob* is of type `PyDateTime_TZInfoType` or a subtype of `PyDateTime_TZInfoType`. *ob* must not be `NULL`. New in version 2.4.

`int PyTZInfo_CheckExact (PyObject *ob)`

Return true if *ob* is of type `PyDateTime_TZInfoType`. *ob* must not be `NULL`. New in version 2.4.

Macros to create objects:

`PyObject* PyDate_FromDate (int year, int month, int day)`

Return value: New reference.

Return a `datetime.date` object with the specified year, month and day. New in version 2.4.

`PyObject* PyDateTime_FromDateAndTime (int year, int month, int day, int hour, int minute, int second, int usecond)`

Return value: New reference.

Return a `datetime.datetime` object with the specified year, month, day, hour, minute, second and microsecond. New in version 2.4.

`PyObject* PyTime_FromTime (int hour, int minute, int second, int usecond)`

Return value: New reference.

Return a `datetime.time` object with the specified hour, minute, second and microsecond. New in version 2.4.

`PyObject* PyDelta_FromDSU (int days, int seconds, int useconds)`

Return value: New reference.

Return a `datetime.timedelta` object representing the given number of days, seconds and microseconds. Normalization is performed so that the resulting number of microseconds and seconds lie in the ranges documented for `datetime.timedelta` objects. New in version 2.4.

Macros to extract fields from date objects. The argument must be an instance of `PyDateTime_Date`, including subclasses (such as `PyDateTime_DateTime`). The argument must not be `NULL`, and the type is not checked:

`int PyDateTime_GET_YEAR (PyDateTime_Date *o)`

Return the year, as a positive int. New in version 2.4.

`int PyDateTime_GET_MONTH (PyDateTime_Date *o)`

Return the month, as an int from 1 through 12. New in version 2.4.

`int PyDateTime_GET_DAY (PyDateTime_Date *o)`

Return the day, as an int from 1 through 31. New in version 2.4.

Macros to extract fields from datetime objects. The argument must be an instance of `PyDateTime_DateTime`, including subclasses. The argument must not be `NULL`, and the type is not checked:

`int PyDateTime_DATE_GET_HOUR (PyDateTime_DateTime *o)`

Return the hour, as an int from 0 through 23. New in version 2.4.

`int PyDateTime_DATE_GET_MINUTE (PyDateTime_DateTime *o)`

Return the minute, as an int from 0 through 59. New in version 2.4.

`int PyDateTime_DATE_GET_SECOND (PyDateTime_DateTime *o)`

Return the second, as an int from 0 through 59. New in version 2.4.

`int PyDateTime_DATE_GET_MICROSECOND (PyDateTime_DateTime *o)`

Return the microsecond, as an int from 0 through 999999. New in version 2.4.

Macros to extract fields from time objects. The argument must be an instance of `PyDateTime_Time`, including subclasses. The argument must not be `NULL`, and the type is not checked:

int **PyDateTime\_TIME\_GET\_HOUR** (PyDateTime\_Time \*o)

Return the hour, as an int from 0 through 23. New in version 2.4.

int **PyDateTime\_TIME\_GET\_MINUTE** (PyDateTime\_Time \*o)

Return the minute, as an int from 0 through 59. New in version 2.4.

int **PyDateTime\_TIME\_GET\_SECOND** (PyDateTime\_Time \*o)

Return the second, as an int from 0 through 59. New in version 2.4.

int **PyDateTime\_TIME\_GET\_MICROSECOND** (PyDateTime\_Time \*o)

Return the microsecond, as an int from 0 through 999999. New in version 2.4.

Macros for the convenience of modules implementing the DB API:

**PyObject\*** **PyDateTime\_FromTimestamp** (PyObject \*args)

*Return value:* New reference.

Create and return a new `datetime.datetime` object given an argument tuple suitable for passing to `datetime.datetime.fromtimestamp()`. New in version 2.4.

**PyObject\*** **PyDate\_FromTimestamp** (PyObject \*args)

*Return value:* New reference.

Create and return a new `datetime.date` object given an argument tuple suitable for passing to `datetime.date.fromtimestamp()`. New in version 2.4.

## 7.5.15 Set Objects

New in version 2.5. This section details the public API for set and frozenset objects. Any functionality not listed below is best accessed using either the abstract object protocol (including `PyObject_CallMethod()`, `PyObject_RichCompareBool()`, `PyObject_Hash()`, `PyObject_Repr()`, `PyObject_IsTrue()`, `PyObject_Print()`, and `PyObject_GetIter()`) or the abstract number protocol (including `PyNumber_And()`, `PyNumber_Subtract()`, `PyNumber_Or()`, `PyNumber_Xor()`, `PyNumber_InPlaceAnd()`, `PyNumber_InPlaceSubtract()`, `PyNumber_InPlaceOr()`, and `PyNumber_InPlaceXor()`).

### PySetObject

This subtype of `PyObject` is used to hold the internal data for both set and frozenset objects. It is like a `PyDictObject` in that it is a fixed size for small sets (much like tuple storage) and will point to a separate, variable sized block of memory for medium and large sized sets (much like list storage). None of the fields of this structure should be considered public and are subject to change. All access should be done through the documented API rather than by manipulating the values in the structure.

### PyTypeObject PySet\_Type

This is an instance of `PyTypeObject` representing the Python set type.

### PyTypeObject PyFrozenSet\_Type

This is an instance of `PyTypeObject` representing the Python frozenset type.

The following type check macros work on pointers to any Python object. Likewise, the constructor functions work with any iterable Python object.

int **PySet\_Check** (PyObject \*p)

Return true if `p` is a set object or an instance of a subtype. New in version 2.6.

int **PyFrozenSet\_Check** (PyObject \*p)

Return true if `p` is a frozenset object or an instance of a subtype. New in version 2.6.

int **PyAnySet\_Check** (PyObject \*p)

Return true if `p` is a set object, a frozenset object, or an instance of a subtype.

`int PyAnySet_CheckExact (PyObject *p)`

Return true if *p* is a `set` object or a `frozenset` object but not an instance of a subtype.

`int PyFrozenSet_CheckExact (PyObject *p)`

Return true if *p* is a `frozenset` object but not an instance of a subtype.

`PyObject* PySet_New (PyObject *iterable)`

*Return value:* New reference.

Return a new `set` containing objects returned by the *iterable*. The *iterable* may be `NULL` to create a new empty set. Return the new set on success or `NULL` on failure. Raise `TypeError` if *iterable* is not actually iterable. The constructor is also useful for copying a set (`c=set (s)`).

`PyObject* PyFrozenSet_New (PyObject *iterable)`

*Return value:* New reference.

Return a new `frozenset` containing objects returned by the *iterable*. The *iterable* may be `NULL` to create a new empty frozenset. Return the new set on success or `NULL` on failure. Raise `TypeError` if *iterable* is not actually iterable. Changed in version 2.6: Now guaranteed to return a brand-new frozenset. Formerly, frozensets of zero-length were a singleton. This got in the way of building-up new frozensets with `PySet_Add()`.

The following functions and macros are available for instances of `set` or `frozenset` or instances of their subtypes.

`Py_ssize_t PySet_Size (PyObject *anyset)`

Return the length of a `set` or `frozenset` object. Equivalent to `len(anyset)`. Raises a `PyExc_SystemError` if *anyset* is not a `set`, `frozenset`, or an instance of a subtype. Changed in version 2.5: This function returned an `int`. This might require changes in your code for properly supporting 64-bit systems.

`Py_ssize_t PySet_GET_SIZE (PyObject *anyset)`

Macro form of `PySet_Size()` without error checking.

`int PySet_Contains (PyObject *anyset, PyObject *key)`

Return 1 if found, 0 if not found, and -1 if an error is encountered. Unlike the Python `__contains__()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise a `TypeError` if the *key* is unhashable. Raise `PyExc_SystemError` if *anyset* is not a `set`, `frozenset`, or an instance of a subtype.

`int PySet_Add (PyObject *set, PyObject *key)`

Add *key* to a `set` instance. Does not apply to `frozenset` instances. Return 0 on success or -1 on failure. Raise a `TypeError` if the *key* is unhashable. Raise a `MemoryError` if there is no room to grow. Raise a `SystemError` if *set* is an not an instance of `set` or its subtype. Changed in version 2.6: Now works with instances of `frozenset` or its subtypes. Like `PyTuple_SetItem()` in that it can be used to fill-in the values of brand new frozensets before they are exposed to other code.

The following functions are available for instances of `set` or its subtypes but not for instances of `frozenset` or its subtypes.

`int PySet_Discard (PyObject *set, PyObject *key)`

Return 1 if found and removed, 0 if not found (no action taken), and -1 if an error is encountered. Does not raise `KeyError` for missing keys. Raise a `TypeError` if the *key* is unhashable. Unlike the Python `discard()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise `PyExc_SystemError` if *set* is an not an instance of `set` or its subtype.

`PyObject* PySet_Pop (PyObject *set)`

*Return value:* New reference.

Return a new reference to an arbitrary object in the *set*, and removes the object from the *set*. Return `NULL` on failure. Raise `KeyError` if the set is empty. Raise a `SystemError` if *set* is an not an instance of `set` or its subtype.

`int PySet_Clear (PyObject *set)`  
 Empty an existing set of all elements.

## 7.5.16 Code Objects

Code objects are a low-level detail of the CPython implementation. Each one represents a chunk of executable code that hasn't yet been bound into a function.

### PyCodeObject

The C structure of the objects used to describe code objects. The fields of this type are subject to change at any time.

### PyTypeObject PyCode\_Type

This is an instance of `PyTypeObject` representing the Python code type.

`int PyCode_Check (PyObject *co)`  
 Return true if `co` is a code object

`int PyCode_GetNumFree (PyObject *co)`  
 Return the number of free variables in `co`.

`PyCodeObject *PyCode_New (int argcount, int nlocals, int stacksize, int flags, PyObject *code, PyObject *consts, PyObject *names, PyObject *varnames, PyObject *freevars, PyObject *cellvars, PyObject *filename, PyObject *name, int firstlineno, PyObject *notab)`

Return a new code object. If you need a dummy code object to create a frame, use `PyCode_NewEmpty()` instead. Calling `PyCode_New()` directly can bind you to a precise Python version since the definition of the bytecode changes often.

`int PyCode_NewEmpty (const char *filename, const char *funcname, int firstlineno)`  
 Return a new empty code object with the specified filename, function name, and first line number. It is illegal to `exec` or `eval()` the resulting code object.



# INITIALIZATION, FINALIZATION, AND THREADS

## 8.1 Initializing and finalizing the interpreter

void `Py_Initialize()`

Initialize the Python interpreter. In an application embedding Python, this should be called before using any other Python/C API functions; with the exception of `Py_SetProgramName()`, `Py_SetPythonHome()`, `PyEval_InitThreads()`, `PyEval_ReleaseLock()`, and `PyEval_AcquireLock()`. This initializes the table of loaded modules (`sys.modules`), and creates the fundamental modules `__builtin__`, `__main__` and `sys`. It also initializes the module search path (`sys.path`). It does not set `sys.argv`; use `PySys_SetArgvEx()` for that. This is a no-op when called for a second time (without calling `Py_Finalize()` first). There is no return value; it is a fatal error if the initialization fails.

void `Py_InitializeEx(int initsigs)`

This function works like `Py_Initialize()` if `initsigs` is 1. If `initsigs` is 0, it skips initialization registration of signal handlers, which might be useful when Python is embedded. New in version 2.4.

int `Py_IsInitialized()`

Return true (nonzero) when the Python interpreter has been initialized, false (zero) if not. After `Py_Finalize()` is called, this returns false until `Py_Initialize()` is called again.

void `Py_Finalize()`

Undo all initializations made by `Py_Initialize()` and subsequent use of Python/C API functions, and destroy all sub-interpreters (see `Py_NewInterpreter()` below) that were created and not yet destroyed since the last call to `Py_Initialize()`. Ideally, this frees all memory allocated by the Python interpreter. This is a no-op when called for a second time (without calling `Py_Initialize()` again first). There is no return value; errors during finalization are ignored.

This function is provided for a number of reasons. An embedding application might want to restart Python without having to restart the application itself. An application that has loaded the Python interpreter from a dynamically loadable library (or DLL) might want to free all memory allocated by Python before unloading the DLL. During a hunt for memory leaks in an application a developer might want to free all memory allocated by Python before exiting from the application.

**Bugs and caveats:** The destruction of modules and objects in modules is done in random order; this may cause destructors (`__del__()` methods) to fail when they depend on other objects (even functions) or modules. Dynamically loaded extension modules loaded by Python are not unloaded. Small amounts of memory allocated by the Python interpreter may not be freed (if you find a leak, please report it). Memory tied up in circular references between objects is not freed. Some memory allocated by extension modules may not be freed. Some extensions may not work properly if their initialization routine is called more than once; this can happen if an application calls `Py_Initialize()` and `Py_Finalize()` more than once.

## 8.2 Process-wide parameters

void **Py\_SetProgramName** (char \*name)

This function should be called before `Py_Initialize()` is called for the first time, if it is called at all. It tells the interpreter the value of the `argv[0]` argument to the `main()` function of the program. This is used by `Py_GetPath()` and some other functions below to find the Python run-time libraries relative to the interpreter executable. The default value is `'python'`. The argument should point to a zero-terminated character string in static storage whose contents will not change for the duration of the program's execution. No code in the Python interpreter will change the contents of this storage.

char\* **Py\_GetProgramName** ()

Return the program name set with `Py_SetProgramName()`, or the default. The returned string points into static storage; the caller should not modify its value.

char\* **Py\_GetPrefix** ()

Return the *prefix* for installed platform-independent files. This is derived through a number of complicated rules from the program name set with `Py_SetProgramName()` and some environment variables; for example, if the program name is `'/usr/local/bin/python'`, the prefix is `'/usr/local'`. The returned string points into static storage; the caller should not modify its value. This corresponds to the **prefix** variable in the top-level `Makefile` and the `--prefix` argument to the **configure** script at build time. The value is available to Python code as `sys.prefix`. It is only useful on Unix. See also the next function.

char\* **Py\_GetExecPrefix** ()

Return the *exec-prefix* for installed platform-dependent files. This is derived through a number of complicated rules from the program name set with `Py_SetProgramName()` and some environment variables; for example, if the program name is `'/usr/local/bin/python'`, the exec-prefix is `'/usr/local'`. The returned string points into static storage; the caller should not modify its value. This corresponds to the **exec\_prefix** variable in the top-level `Makefile` and the `--exec-prefix` argument to the **configure** script at build time. The value is available to Python code as `sys.exec_prefix`. It is only useful on Unix.

Background: The *exec-prefix* differs from the *prefix* when platform dependent files (such as executables and shared libraries) are installed in a different directory tree. In a typical installation, platform dependent files may be installed in the `/usr/local/plat` subtree while platform independent may be installed in `/usr/local`.

Generally speaking, a platform is a combination of hardware and software families, e.g. Sparc machines running the Solaris 2.x operating system are considered the same platform, but Intel machines running Solaris 2.x are another platform, and Intel machines running Linux are yet another platform. Different major revisions of the same operating system generally also form different platforms. Non-Unix operating systems are a different story; the installation strategies on those systems are so different that the *prefix* and *exec-prefix* are meaningless, and set to the empty string. Note that compiled Python bytecode files are platform independent (but not independent from the Python version by which they were compiled!).

System administrators will know how to configure the **mount** or **automount** programs to share `/usr/local` between platforms while having `/usr/local/plat` be a different filesystem for each platform.

char\* **Py\_GetProgramFullPath** ()

Return the full program name of the Python executable; this is computed as a side-effect of deriving the default module search path from the program name (set by `Py_SetProgramName()` above). The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.executable`.

char\* **Py\_GetPath** ()

Return the default module search path; this is computed from the program name (set by `Py_SetProgramName()` above) and some environment variables. The returned string consists of a series of directory names separated by a platform dependent delimiter character. The delimiter character is `':'` on Unix and Mac OS X,  `';'`  on Windows. The returned string points into static storage; the caller should not modify its

value. The list `sys.path` is initialized with this value on interpreter startup; it can be (and usually is) modified later to change the search path for loading modules.

const char\* **Py\_GetVersion** ()

Return the version of this Python interpreter. This is a string that looks something like

```
"1.5 (#67, Dec 31 1997, 22:34:28) [GCC 2.7.2.2]"
```

The first word (up to the first space character) is the current Python version; the first three characters are the major and minor version separated by a period. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.version`.

const char\* **Py\_GetPlatform** ()

Return the platform identifier for the current platform. On Unix, this is formed from the “official” name of the operating system, converted to lower case, followed by the major revision number; e.g., for Solaris 2.x, which is also known as SunOS 5.x, the value is `'sunos5'`. On Mac OS X, it is `'darwin'`. On Windows, it is `'win'`. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.platform`.

const char\* **Py\_GetCopyright** ()

Return the official copyright string for the current Python version, for example

```
'Copyright 1991-1995 Stichting Mathematisch Centrum, Amsterdam'
```

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.copyright`.

const char\* **Py\_GetCompiler** ()

Return an indication of the compiler used to build the current Python version, in square brackets, for example:

```
" [GCC 2.7.2.2] "
```

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable `sys.version`.

const char\* **Py\_GetBuildInfo** ()

Return information about the sequence number and build date and time of the current Python interpreter instance, for example

```
"#67, Aug 1 1997, 22:34:28"
```

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable `sys.version`.

void **PySys\_SetArgvEx** (int *argc*, char \*\**argv*, int *updatepath*)

Set `sys.argv` based on *argc* and *argv*. These parameters are similar to those passed to the program’s `main` () function with the difference that the first entry should refer to the script file to be executed rather than the executable hosting the Python interpreter. If there isn’t a script that will be run, the first entry in *argv* can be an empty string. If this function fails to initialize `sys.argv`, a fatal condition is signalled using `Py_FatalError` ().

If *updatepath* is zero, this is all the function does. If *updatepath* is non-zero, the function also modifies `sys.path` according to the following algorithm:

- If the name of an existing script is passed in `argv[0]`, the absolute path of the directory where the script is located is prepended to `sys.path`.
- Otherwise (that is, if *argc* is 0 or `argv[0]` doesn’t point to an existing file name), an empty string is prepended to `sys.path`, which is the same as prepending the current working directory ( `"."`).

**Note:** It is recommended that applications embedding the Python interpreter for purposes other than executing a single script pass 0 as *updatepath*, and update `sys.path` themselves if desired. See CVE-2008-5983.

On versions before 2.6.6, you can achieve the same effect by manually popping the first `sys.path` element after having called `PySys_SetArgv()`, for example using:

```
PyRun_SimpleString("import sys; sys.path.pop(0)\n");
```

---

New in version 2.6.6.

void **PySys\_SetArgv** (int *argc*, char \*\**argv*)

This function works like `PySys_SetArgvEx()` with *updatepath* set to 1.

void **Py\_SetPythonHome** (char \**home*)

Set the default “home” directory, that is, the location of the standard Python libraries. See `PYTHONHOME` for the meaning of the argument string.

The argument should point to a zero-terminated character string in static storage whose contents will not change for the duration of the program’s execution. No code in the Python interpreter will change the contents of this storage.

char\* **Py\_GetPythonHome** ()

Return the default “home”, that is, the value set by a previous call to `Py_SetPythonHome()`, or the value of the `PYTHONHOME` environment variable if it is set.

## 8.3 Thread State and the Global Interpreter Lock

The Python interpreter is not fully thread-safe. In order to support multi-threaded Python programs, there’s a global lock, called the *global interpreter lock* or *GIL*, that must be held by the current thread before it can safely access Python objects. Without the lock, even the simplest operations could cause problems in a multi-threaded program: for example, when two threads simultaneously increment the reference count of the same object, the reference count could end up being incremented only once instead of twice.

Therefore, the rule exists that only the thread that has acquired the *GIL* may operate on Python objects or call Python/C API functions. In order to emulate concurrency of execution, the interpreter regularly tries to switch threads (see `sys.setcheckinterval()`). The lock is also released around potentially blocking I/O operations like reading or writing a file, so that other Python threads can run in the meantime.

The Python interpreter keeps some thread-specific bookkeeping information inside a data structure called `PyThreadState`. There’s also one global variable pointing to the current `PyThreadState`: it can be retrieved using `PyThreadState_Get()`.

### 8.3.1 Releasing the GIL from extension code

Most extension code manipulating the *GIL* has the following simple structure:

```
Save the thread state in a local variable.  
Release the global interpreter lock.  
... Do some blocking I/O operation ...  
Reacquire the global interpreter lock.  
Restore the thread state from the local variable.
```

This is so common that a pair of macros exists to simplify it:

```
Py_BEGIN_ALLOW_THREADS
... Do some blocking I/O operation ...
Py_END_ALLOW_THREADS
```

The `Py_BEGIN_ALLOW_THREADS` macro opens a new block and declares a hidden local variable; the `Py_END_ALLOW_THREADS` macro closes the block. These two macros are still available when Python is compiled without thread support (they simply have an empty expansion).

When thread support is enabled, the block above expands to the following code:

```
PyThreadState *_save;

_save = PyEval_SaveThread();
...Do some blocking I/O operation...
PyEval_RestoreThread(_save);
```

Here is how these functions work: the global interpreter lock is used to protect the pointer to the current thread state. When releasing the lock and saving the thread state, the current thread state pointer must be retrieved before the lock is released (since another thread could immediately acquire the lock and store its own thread state in the global variable). Conversely, when acquiring the lock and restoring the thread state, the lock must be acquired before storing the thread state pointer.

---

**Note:** Calling system I/O functions is the most common use case for releasing the GIL, but it can also be useful before calling long-running computations which don't need access to Python objects, such as compression or cryptographic functions operating over memory buffers. For example, the standard `zlib` and `hashlib` modules release the GIL when compressing or hashing data.

---

### 8.3.2 Non-Python created threads

When threads are created using the dedicated Python APIs (such as the `threading` module), a thread state is automatically associated to them and the code showed above is therefore correct. However, when threads are created from C (for example by a third-party library with its own thread management), they don't hold the GIL, nor is there a thread state structure for them.

If you need to call Python code from these threads (often this will be part of a callback API provided by the aforementioned third-party library), you must first register these threads with the interpreter by creating a thread state data structure, then acquiring the GIL, and finally storing their thread state pointer, before you can start using the Python/C API. When you are done, you should reset the thread state pointer, release the GIL, and finally free the thread state data structure.

The `PyGILState_Ensure()` and `PyGILState_Release()` functions do all of the above automatically. The typical idiom for calling into Python from a C thread is:

```
PyGILState_STATE gstate;
gstate = PyGILState_Ensure();

/* Perform Python actions here. */
result = CallSomeFunction();
/* evaluate result or handle exception */

/* Release the thread. No Python API allowed beyond this point. */
PyGILState_Release(gstate);
```

Note that the `PyGILState_*()` functions assume there is only one global interpreter (created automatically by `Py_Initialize()`). Python supports the creation of additional interpreters (using `Py_NewInterpreter()`), but mixing multiple interpreters and the `PyGILState_*()` API is unsupported.

Another important thing to note about threads is their behaviour in the face of the C `fork()` call. On most systems with `fork()`, after a process forks only the thread that issued the fork will exist. That also means any locks held by other threads will never be released. Python solves this for `os.fork()` by acquiring the locks it uses internally before the fork, and releasing them afterwards. In addition, it resets any *lock-objects* in the child. When extending or embedding Python, there is no way to inform Python of additional (non-Python) locks that need to be acquired before or reset after a fork. OS facilities such as `pthread_atfork()` would need to be used to accomplish the same thing. Additionally, when extending or embedding Python, calling `fork()` directly rather than through `os.fork()` (and returning to or calling into Python) may result in a deadlock by one of Python's internal locks being held by a thread that is defunct after the fork. `PyOS_AfterFork()` tries to reset the necessary locks, but is not always able to.

### 8.3.3 High-level API

These are the most commonly used types and functions when writing C extension code, or when embedding the Python interpreter:

#### **PyInterpreterState**

This data structure represents the state shared by a number of cooperating threads. Threads belonging to the same interpreter share their module administration and a few other internal items. There are no public members in this structure.

Threads belonging to different interpreters initially share nothing, except process state like available memory, open file descriptors and such. The global interpreter lock is also shared by all threads, regardless of to which interpreter they belong.

#### **PyThreadState**

This data structure represents the state of a single thread. The only public data member is `PyInterpreterState *interp`, which points to this thread's interpreter state.

#### **void PyEval\_InitThreads()**

Initialize and acquire the global interpreter lock. It should be called in the main thread before creating a second thread or engaging in any other thread operations such as `PyEval_ReleaseLock()` or `PyEval_ReleaseThread(tstate)`. It is not needed before calling `PyEval_SaveThread()` or `PyEval_RestoreThread()`.

This is a no-op when called for a second time. It is safe to call this function before calling `Py_Initialize()`.

---

**Note:** When only the main thread exists, no GIL operations are needed. This is a common situation (most Python programs do not use threads), and the lock operations slow the interpreter down a bit. Therefore, the lock is not created initially. This situation is equivalent to having acquired the lock: when there is only a single thread, all object accesses are safe. Therefore, when this function initializes the global interpreter lock, it also acquires it. Before the Python `_thread` module creates a new thread, knowing that either it has the lock or the lock hasn't been created yet, it calls `PyEval_InitThreads()`. When this call returns, it is guaranteed that the lock has been created and that the calling thread has acquired it.

It is **not** safe to call this function when it is unknown which thread (if any) currently has the global interpreter lock.

This function is not available when thread support is disabled at compile time.

---

#### **int PyEval\_ThreadsInitialized()**

Returns a non-zero value if `PyEval_InitThreads()` has been called. This function can be called without holding the GIL, and therefore can be used to avoid calls to the locking API when running single-threaded. This function is not available when thread support is disabled at compile time. New in version 2.4.

#### **PyThreadState\* PyEval\_SaveThread()**

Release the global interpreter lock (if it has been created and thread support is enabled) and reset the thread

state to *NULL*, returning the previous thread state (which is not *NULL*). If the lock has been created, the current thread must have acquired it. (This function is available even when thread support is disabled at compile time.)

void **PyEval\_RestoreThread** (PyThreadState \*tstate)

Acquire the global interpreter lock (if it has been created and thread support is enabled) and set the thread state to *tstate*, which must not be *NULL*. If the lock has been created, the current thread must not have acquired it, otherwise deadlock ensues. (This function is available even when thread support is disabled at compile time.)

PyThreadState\* **PyThreadState\_Get** ()

Return the current thread state. The global interpreter lock must be held. When the current thread state is *NULL*, this issues a fatal error (so that the caller needn't check for *NULL*).

PyThreadState\* **PyThreadState\_Swap** (PyThreadState \*tstate)

Swap the current thread state with the thread state given by the argument *tstate*, which may be *NULL*. The global interpreter lock must be held and is not released.

void **PyEval\_ReInitThreads** ()

This function is called from `PyOS_AfterFork()` to ensure that newly created child processes don't hold locks referring to threads which are not running in the child process.

The following functions use thread-local storage, and are not compatible with sub-interpreters:

PyGILState\_STATE **PyGILState\_Ensure** ()

Ensure that the current thread is ready to call the Python C API regardless of the current state of Python, or of the global interpreter lock. This may be called as many times as desired by a thread as long as each call is matched with a call to `PyGILState_Release()`. In general, other thread-related APIs may be used between `PyGILState_Ensure()` and `PyGILState_Release()` calls as long as the thread state is restored to its previous state before the `Release()`. For example, normal usage of the `Py_BEGIN_ALLOW_THREADS` and `Py_END_ALLOW_THREADS` macros is acceptable.

The return value is an opaque "handle" to the thread state when `PyGILState_Ensure()` was called, and must be passed to `PyGILState_Release()` to ensure Python is left in the same state. Even though recursive calls are allowed, these handles *cannot* be shared - each unique call to `PyGILState_Ensure()` must save the handle for its call to `PyGILState_Release()`.

When the function returns, the current thread will hold the GIL and be able to call arbitrary Python code. Failure is a fatal error. New in version 2.3.

void **PyGILState\_Release** (PyGILState\_STATE)

Release any resources previously acquired. After this call, Python's state will be the same as it was prior to the corresponding `PyGILState_Ensure()` call (but generally this state will be unknown to the caller, hence the use of the GILState API).

Every call to `PyGILState_Ensure()` must be matched by a call to `PyGILState_Release()` on the same thread. New in version 2.3.

PyThreadState **PyGILState\_GetThisThreadState** ()

Get the current thread state for this thread. May return *NULL* if no GILState API has been used on the current thread. Note that the main thread always has such a thread-state, even if no auto-thread-state call has been made on the main thread. This is mainly a helper/diagnostic function. New in version 2.3.

The following macros are normally used without a trailing semicolon; look for example usage in the Python source distribution.

**Py\_BEGIN\_ALLOW\_THREADS**

This macro expands to `{ PyThreadState *_save; _save = PyEval_SaveThread();`. Note that it contains an opening brace; it must be matched with a following `Py_END_ALLOW_THREADS` macro. See above for further discussion of this macro. It is a no-op when thread support is disabled at compile time.

**Py\_END\_ALLOW\_THREADS**

This macro expands to `PyEval_RestoreThread(_save); }`. Note that it contains a closing brace; it

must be matched with an earlier `Py_BEGIN_ALLOW_THREADS` macro. See above for further discussion of this macro. It is a no-op when thread support is disabled at compile time.

### **Py\_BLOCK\_THREADS**

This macro expands to `PyEval_RestoreThread(_save);`; it is equivalent to `Py_END_ALLOW_THREADS` without the closing brace. It is a no-op when thread support is disabled at compile time.

### **Py\_UNBLOCK\_THREADS**

This macro expands to `_save = PyEval_SaveThread();`; it is equivalent to `Py_BEGIN_ALLOW_THREADS` without the opening brace and variable declaration. It is a no-op when thread support is disabled at compile time.

## 8.3.4 Low-level API

All of the following functions are only available when thread support is enabled at compile time, and must be called only when the global interpreter lock has been created.

### `PyInterpreterState*` **PyInterpreterState\_New** ()

Create a new interpreter state object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.

### `void` **PyInterpreterState\_Clear** (`PyInterpreterState *interp`)

Reset all information in an interpreter state object. The global interpreter lock must be held.

### `void` **PyInterpreterState\_Delete** (`PyInterpreterState *interp`)

Destroy an interpreter state object. The global interpreter lock need not be held. The interpreter state must have been reset with a previous call to `PyInterpreterState_Clear()`.

### `PyThreadState*` **PyThreadState\_New** (`PyInterpreterState *interp`)

Create a new thread state object belonging to the given interpreter object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.

### `void` **PyThreadState\_Clear** (`PyThreadState *tstate`)

Reset all information in a thread state object. The global interpreter lock must be held.

### `void` **PyThreadState\_Delete** (`PyThreadState *tstate`)

Destroy a thread state object. The global interpreter lock need not be held. The thread state must have been reset with a previous call to `PyThreadState_Clear()`.

### `PyObject*` **PyThreadState\_GetDict** ()

*Return value: Borrowed reference.*

Return a dictionary in which extensions can store thread-specific state information. Each extension should use a unique key to use to store state in the dictionary. It is okay to call this function when no current thread state is available. If this function returns `NULL`, no exception has been raised and the caller should assume no current thread state is available. Changed in version 2.3: Previously this could only be called when a current thread is active, and `NULL` meant that an exception was raised.

### `int` **PyThreadState\_SetAsyncExc** (`long id`, `PyObject *exc`)

Asynchronously raise an exception in a thread. The `id` argument is the thread id of the target thread; `exc` is the exception object to be raised. This function does not steal any references to `exc`. To prevent naive misuse, you must write your own C extension to call this. Must be called with the GIL held. Returns the number of thread states modified; this is normally one, but will be zero if the thread id isn't found. If `exc` is `NULL`, the pending exception (if any) for the thread is cleared. This raises no exceptions. New in version 2.3.

### `void` **PyEval\_AcquireThread** (`PyThreadState *tstate`)

Acquire the global interpreter lock and set the current thread state to `tstate`, which should not be `NULL`. The lock must have been created earlier. If this thread already has the lock, deadlock ensues.

`PyEval_RestoreThread()` is a higher-level function which is always available (even when thread support isn't enabled or when threads have not been initialized).

void **PyEval\_ReleaseThread** (`PyThreadState *tstate`)

Reset the current thread state to `NULL` and release the global interpreter lock. The lock must have been created earlier and must be held by the current thread. The `tstate` argument, which must not be `NULL`, is only used to check that it represents the current thread state — if it isn't, a fatal error is reported.

`PyEval_SaveThread()` is a higher-level function which is always available (even when thread support isn't enabled or when threads have not been initialized).

void **PyEval\_AcquireLock** ()

Acquire the global interpreter lock. The lock must have been created earlier. If this thread already has the lock, a deadlock ensues.

**Warning:** This function does not change the current thread state. Please use `PyEval_RestoreThread()` or `PyEval_AcquireThread()` instead.

void **PyEval\_ReleaseLock** ()

Release the global interpreter lock. The lock must have been created earlier.

**Warning:** This function does not change the current thread state. Please use `PyEval_SaveThread()` or `PyEval_ReleaseThread()` instead.

## 8.4 Sub-interpreter support

While in most uses, you will only embed a single Python interpreter, there are cases where you need to create several independent interpreters in the same process and perhaps even in the same thread. Sub-interpreters allow you to do that. You can switch between sub-interpreters using the `PyThreadState_Swap()` function. You can create and destroy them using the following functions:

`PyThreadState*` **Py\_NewInterpreter** ()

Create a new sub-interpreter. This is an (almost) totally separate environment for the execution of Python code. In particular, the new interpreter has separate, independent versions of all imported modules, including the fundamental modules `builtins`, `__main__` and `sys`. The table of loaded modules (`sys.modules`) and the module search path (`sys.path`) are also separate. The new environment has no `sys.argv` variable. It has new standard I/O stream file objects `sys.stdin`, `sys.stdout` and `sys.stderr` (however these refer to the same underlying file descriptors).

The return value points to the first thread state created in the new sub-interpreter. This thread state is made in the current thread state. Note that no actual thread is created; see the discussion of thread states below. If creation of the new interpreter is unsuccessful, `NULL` is returned; no exception is set since the exception state is stored in the current thread state and there may not be a current thread state. (Like all other Python/C API functions, the global interpreter lock must be held before calling this function and is still held when it returns; however, unlike most other Python/C API functions, there needn't be a current thread state on entry.)

Extension modules are shared between (sub-)interpreters as follows: the first time a particular extension is imported, it is initialized normally, and a (shallow) copy of its module's dictionary is squirreled away. When the same extension is imported by another (sub-)interpreter, a new module is initialized and filled with the contents of this copy; the extension's `init` function is not called. Note that this is different from what happens when an extension is imported after the interpreter has been completely re-initialized by calling `Py_Finalize()` and `Py_Initialize()`; in that case, the extension's `initmodule` function is called again.

void **Py\_EndInterpreter** (`PyThreadState *tstate`)

Destroy the (sub-)interpreter represented by the given thread state. The given thread state must be the current

thread state. See the discussion of thread states below. When the call returns, the current thread state is *NULL*. All thread states associated with this interpreter are destroyed. (The global interpreter lock must be held before calling this function and is still held when it returns.) `Py_Finalize()` will destroy all sub-interpreters that haven't been explicitly destroyed at that point.

### 8.4.1 Bugs and caveats

Because sub-interpreters (and the main interpreter) are part of the same process, the insulation between them isn't perfect — for example, using low-level file operations like `os.close()` they can (accidentally or maliciously) affect each other's open files. Because of the way extensions are shared between (sub-)interpreters, some extensions may not work properly; this is especially likely when the extension makes use of (static) global variables, or when the extension manipulates its module's dictionary after its initialization. It is possible to insert objects created in one sub-interpreter into a namespace of another sub-interpreter; this should be done with great care to avoid sharing user-defined functions, methods, instances or classes between sub-interpreters, since import operations executed by such objects may affect the wrong (sub-)interpreter's dictionary of loaded modules.

Also note that combining this functionality with `PyGILState_*()` APIs is delicate, because these APIs assume a bijection between Python thread states and OS-level threads, an assumption broken by the presence of sub-interpreters. It is highly recommended that you don't switch sub-interpreters between a pair of matching `PyGILState_Ensure()` and `PyGILState_Release()` calls. Furthermore, extensions (such as `ctypes`) using these APIs to allow calling of Python code from non-Python created threads will probably be broken when using sub-interpreters.

## 8.5 Asynchronous Notifications

A mechanism is provided to make asynchronous notifications to the main interpreter thread. These notifications take the form of a function pointer and a void argument.

Every check interval, when the global interpreter lock is released and reacquired, Python will also call any such provided functions. This can be used for example by asynchronous IO handlers. The notification can be scheduled from a worker thread and the actual call than made at the earliest convenience by the main thread where it has possession of the global interpreter lock and can perform any Python API calls.

int `Py_AddPendingCall`(int (\*func)(void \*), void \*arg)

Post a notification to the Python main thread. If successful, *func* will be called with the argument *arg* at the earliest convenience. *func* will be called having the global interpreter lock held and can thus use the full Python API and can take any action such as setting object attributes to signal IO completion. It must return 0 on success, or -1 signalling an exception. The notification function won't be interrupted to perform another asynchronous notification recursively, but it can still be interrupted to switch threads if the global interpreter lock is released, for example, if it calls back into Python code.

This function returns 0 on success in which case the notification has been scheduled. Otherwise, for example if the notification buffer is full, it returns -1 without setting any exception.

This function can be called on any thread, be it a Python thread or some other system thread. If it is a Python thread, it doesn't matter if it holds the global interpreter lock or not. New in version 2.7.

## 8.6 Profiling and Tracing

The Python interpreter provides some low-level support for attaching profiling and execution tracing facilities. These are used for profiling, debugging, and coverage analysis tools.

Starting with Python 2.2, the implementation of this facility was substantially revised, and an interface from C was added. This C interface allows the profiling or tracing code to avoid the overhead of calling through Python-level

callable objects, making a direct C function call instead. The essential attributes of the facility have not changed; the interface allows trace functions to be installed per-thread, and the basic events reported to the trace function are the same as had been reported to the Python-level trace functions in previous versions.

int (**\*Py\_tracefunc**) (PyObject \*obj, PyFrameObject \*frame, int what, PyObject \*arg)

The type of the trace function registered using `PyEval_SetProfile()` and `PyEval_SetTrace()`. The first parameter is the object passed to the registration function as *obj*, *frame* is the frame object to which the event pertains, *what* is one of the constants `PyTrace_CALL`, `PyTrace_EXCEPTION`, `PyTrace_LINE`, `PyTrace_RETURN`, `PyTrace_C_CALL`, `PyTrace_C_EXCEPTION`, or `PyTrace_C_RETURN`, and *arg* depends on the value of *what*:

| Value of <i>what</i>             | Meaning of <i>arg</i>                                                               |
|----------------------------------|-------------------------------------------------------------------------------------|
| <code>PyTrace_CALL</code>        | Always <code>NULL</code> .                                                          |
| <code>PyTrace_EXCEPTION</code>   | Exception information as returned by <code>sys.exc_info()</code> .                  |
| <code>PyTrace_LINE</code>        | Always <code>NULL</code> .                                                          |
| <code>PyTrace_RETURN</code>      | Value being returned to the caller, or <code>NULL</code> if caused by an exception. |
| <code>PyTrace_C_CALL</code>      | Function object being called.                                                       |
| <code>PyTrace_C_EXCEPTION</code> | Function object being called.                                                       |
| <code>PyTrace_C_RETURN</code>    | Function object being called.                                                       |

int **PyTrace\_CALL**

The value of the *what* parameter to a `Py_tracefunc` function when a new call to a function or method is being reported, or a new entry into a generator. Note that the creation of the iterator for a generator function is not reported as there is no control transfer to the Python bytecode in the corresponding frame.

int **PyTrace\_EXCEPTION**

The value of the *what* parameter to a `Py_tracefunc` function when an exception has been raised. The callback function is called with this value for *what* when after any bytecode is processed after which the exception becomes set within the frame being executed. The effect of this is that as exception propagation causes the Python stack to unwind, the callback is called upon return to each frame as the exception propagates. Only trace functions receives these events; they are not needed by the profiler.

int **PyTrace\_LINE**

The value passed as the *what* parameter to a trace function (but not a profiling function) when a line-number event is being reported.

int **PyTrace\_RETURN**

The value for the *what* parameter to `Py_tracefunc` functions when a call is returning without propagating an exception.

int **PyTrace\_C\_CALL**

The value for the *what* parameter to `Py_tracefunc` functions when a C function is about to be called.

int **PyTrace\_C\_EXCEPTION**

The value for the *what* parameter to `Py_tracefunc` functions when a C function has raised an exception.

int **PyTrace\_C\_RETURN**

The value for the *what* parameter to `Py_tracefunc` functions when a C function has returned.

void **PyEval\_SetProfile** (`Py_tracefunc func`, PyObject \*obj)

Set the profiler function to *func*. The *obj* parameter is passed to the function as its first parameter, and may be any Python object, or `NULL`. If the profile function needs to maintain state, using a different value for *obj* for each thread provides a convenient and thread-safe place to store it. The profile function is called for all monitored events except the line-number events.

void **PyEval\_SetTrace** (`Py_tracefunc func`, PyObject \*obj)

Set the tracing function to *func*. This is similar to `PyEval_SetProfile()`, except the tracing function does receive line-number events.

`PyObject*` **PyEval\_GetCallStats** (`PyObject` \*self)

Return a tuple of function call counts. There are constants defined for the positions within the tuple:

| Name                  | Value |
|-----------------------|-------|
| PCALL_ALL             | 0     |
| PCALL_FUNCTION        | 1     |
| PCALL_FAST_FUNCTION   | 2     |
| PCALL_FASTER_FUNCTION | 3     |
| PCALL_METHOD          | 4     |
| PCALL_BOUND_METHOD    | 5     |
| PCALL_CFUNCTION       | 6     |
| PCALL_TYPE            | 7     |
| PCALL_GENERATOR       | 8     |
| PCALL_OTHER           | 9     |
| PCALL_POP             | 10    |

`PCALL_FAST_FUNCTION` means no argument tuple needs to be created. `PCALL_FASTER_FUNCTION` means that the fast-path frame setup code is used.

If there is a method call where the call can be optimized by changing the argument tuple and calling the function directly, it gets recorded twice.

This function is only present if Python is compiled with `CALL_PROFILE` defined.

## 8.7 Advanced Debugger Support

These functions are only intended to be used by advanced debugging tools.

`PyInterpreterState*` **PyInterpreterState\_Head** ()

Return the interpreter state object at the head of the list of all such objects. New in version 2.2.

`PyInterpreterState*` **PyInterpreterState\_Next** (`PyInterpreterState` \*interp)

Return the next interpreter state object after *interp* from the list of all such objects. New in version 2.2.

`PyThreadState` \* **PyInterpreterState\_ThreadHead** (`PyInterpreterState` \*interp)

Return the a pointer to the first `PyThreadState` object in the list of threads associated with the interpreter *interp*. New in version 2.2.

`PyThreadState*` **PyThreadState\_Next** (`PyThreadState` \*tstate)

Return the next thread state object after *tstate* from the list of all such objects belonging to the same `PyInterpreterState` object. New in version 2.2.

# MEMORY MANAGEMENT

## 9.1 Overview

Memory management in Python involves a private heap containing all Python objects and data structures. The management of this private heap is ensured internally by the *Python memory manager*. The Python memory manager has different components which deal with various dynamic storage management aspects, like sharing, segmentation, preallocation or caching.

At the lowest level, a raw memory allocator ensures that there is enough room in the private heap for storing all Python-related data by interacting with the memory manager of the operating system. On top of the raw memory allocator, several object-specific allocators operate on the same heap and implement distinct memory management policies adapted to the peculiarities of every object type. For example, integer objects are managed differently within the heap than strings, tuples or dictionaries because integers imply different storage requirements and speed/space tradeoffs. The Python memory manager thus delegates some of the work to the object-specific allocators, but ensures that the latter operate within the bounds of the private heap.

It is important to understand that the management of the Python heap is performed by the interpreter itself and that the user has no control over it, even if she regularly manipulates object pointers to memory blocks inside that heap. The allocation of heap space for Python objects and other internal buffers is performed on demand by the Python memory manager through the Python/C API functions listed in this document.

To avoid memory corruption, extension writers should never try to operate on Python objects with the functions exported by the C library: `malloc()`, `calloc()`, `realloc()` and `free()`. This will result in mixed calls between the C allocator and the Python memory manager with fatal consequences, because they implement different algorithms and operate on different heaps. However, one may safely allocate and release memory blocks with the C library allocator for individual purposes, as shown in the following example:

```
PyObject *res;
char *buf = (char *) malloc(BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
...Do some I/O operation involving buf...
res = PyString_FromString(buf);
free(buf); /* malloc'ed */
return res;
```

In this example, the memory request for the I/O buffer is handled by the C library allocator. The Python memory manager is involved only in the allocation of the string object returned as a result.

In most situations, however, it is recommended to allocate memory from the Python heap specifically because the latter is under control of the Python memory manager. For example, this is required when the interpreter is extended with new object types written in C. Another reason for using the Python heap is the desire to *inform* the Python memory

manager about the memory needs of the extension module. Even when the requested memory is used exclusively for internal, highly-specific purposes, delegating all memory requests to the Python memory manager causes the interpreter to have a more accurate image of its memory footprint as a whole. Consequently, under certain circumstances, the Python memory manager may or may not trigger appropriate actions, like garbage collection, memory compaction or other preventive procedures. Note that by using the C library allocator as shown in the previous example, the allocated memory for the I/O buffer escapes completely the Python memory manager.

## 9.2 Memory Interface

The following function sets, modeled after the ANSI C standard, but specifying behavior when requesting zero bytes, are available for allocating and releasing memory from the Python heap:

void\* **PyMem\_Malloc** (size\_t *n*)

Allocates *n* bytes and returns a pointer of type `void*` to the allocated memory, or `NULL` if the request fails. Requesting zero bytes returns a distinct non-`NULL` pointer if possible, as if `PyMem_Malloc(1)` had been called instead. The memory will not have been initialized in any way.

void\* **PyMem\_Realloc** (void \**p*, size\_t *n*)

Resizes the memory block pointed to by *p* to *n* bytes. The contents will be unchanged to the minimum of the old and the new sizes. If *p* is `NULL`, the call is equivalent to `PyMem_Malloc(n)`; else if *n* is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-`NULL`. Unless *p* is `NULL`, it must have been returned by a previous call to `PyMem_Malloc()` or `PyMem_Realloc()`. If the request fails, `PyMem_Realloc()` returns `NULL` and *p* remains a valid pointer to the previous memory area.

void **PyMem\_Free** (void \**p*)

Frees the memory block pointed to by *p*, which must have been returned by a previous call to `PyMem_Malloc()` or `PyMem_Realloc()`. Otherwise, or if `PyMem_Free(p)` has been called before, undefined behavior occurs. If *p* is `NULL`, no operation is performed.

The following type-oriented macros are provided for convenience. Note that *TYPE* refers to any C type.

TYPE\* **PyMem\_New** (TYPE, size\_t *n*)

Same as `PyMem_Malloc()`, but allocates  $(n * \text{sizeof}(TYPE))$  bytes of memory. Returns a pointer cast to `TYPE*`. The memory will not have been initialized in any way.

TYPE\* **PyMem\_Resize** (void \**p*, TYPE, size\_t *n*)

Same as `PyMem_Realloc()`, but the memory block is resized to  $(n * \text{sizeof}(TYPE))$  bytes. Returns a pointer cast to `TYPE*`. On return, *p* will be a pointer to the new memory area, or `NULL` in the event of failure. This is a C preprocessor macro; *p* is always reassigned. Save the original value of *p* to avoid losing memory when handling errors.

void **PyMem\_Del** (void \**p*)

Same as `PyMem_Free()`.

In addition, the following macro sets are provided for calling the Python memory allocator directly, without involving the C API functions listed above. However, note that their use does not preserve binary compatibility across Python versions and is therefore deprecated in extension modules.

`PyMem_MALLOC()`, `PyMem_REALLOC()`, `PyMem_FREE()`.

`PyMem_NEW()`, `PyMem_RESIZE()`, `PyMem_DEL()`.

## 9.3 Examples

Here is the example from section *Overview*, rewritten so that the I/O buffer is allocated from the Python heap by using the first function set:

```

PyObject *res;
char *buf = (char *) PyMem_Malloc(BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyString_FromString(buf);
PyMem_Free(buf); /* allocated with PyMem_Malloc */
return res;

```

The same code using the type-oriented function set:

```

PyObject *res;
char *buf = PyMem_New(char, BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyString_FromString(buf);
PyMem_Del(buf); /* allocated with PyMem_New */
return res;

```

Note that in the two examples above, the buffer is always manipulated via functions belonging to the same set. Indeed, it is required to use the same memory API family for a given memory block, so that the risk of mixing different allocators is reduced to a minimum. The following code sequence contains two errors, one of which is labeled as *fatal* because it mixes two different allocators operating on different heaps.

```

char *buf1 = PyMem_New(char, BUFSIZ);
char *buf2 = (char *) malloc(BUFSIZ);
char *buf3 = (char *) PyMem_Malloc(BUFSIZ);
...
PyMem_Del(buf3); /* Wrong -- should be PyMem_Free() */
free(buf2);      /* Right -- allocated via malloc() */
free(buf1);      /* Fatal -- should be PyMem_Del() */

```

In addition to the functions aimed at handling raw memory blocks from the Python heap, objects in Python are allocated and released with `PyObject_New()`, `PyObject_NewVar()` and `PyObject_Del()`.

These will be explained in the next chapter on defining and implementing new object types in C.



# OBJECT IMPLEMENTATION SUPPORT

This chapter describes the functions, types, and macros used when defining new object types.

## 10.1 Allocating Objects on the Heap

`PyObject* PyObject_New (PyTypeObject *type)`

*Return value:* New reference.

`PyVarObject* PyObject_NewVar (PyTypeObject *type, Py_ssize_t size)`

*Return value:* New reference.

Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

`void PyObject_Del (PyObject *op)`

`PyObject* PyObject_Init (PyObject *op, PyTypeObject *type)`

*Return value:* Borrowed reference.

Initialize a newly-allocated object `op` with its type and initial reference. Returns the initialized object. If `type` indicates that the object participates in the cyclic garbage detector, it is added to the detector's set of observed objects. Other fields of the object are not affected.

`PyVarObject* PyObject_InitVar (PyVarObject *op, PyTypeObject *type, Py_ssize_t size)`

*Return value:* Borrowed reference.

This does everything `PyObject_Init ()` does, and also initializes the length information for a variable-size object. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

`TYPE* PyObject_New (TYPE, PyTypeObject *type)`

*Return value:* New reference.

Allocate a new Python object using the C structure type `TYPE` and the Python type object `type`. Fields not defined by the Python object header are not initialized; the object's reference count will be one. The size of the memory allocation is determined from the `tp_basicsize` field of the type object.

`TYPE* PyObject_NewVar (TYPE, PyTypeObject *type, Py_ssize_t size)`

*Return value:* New reference.

Allocate a new Python object using the C structure type `TYPE` and the Python type object `type`. Fields not defined by the Python object header are not initialized. The allocated memory allows for the `TYPE` structure plus `size` fields of the size given by the `tp_itemsize` field of `type`. This is useful for implementing objects like tuples, which are able to determine their size at construction time. Embedding the array of fields into the same allocation decreases the number of allocations, improving the memory management efficiency. Changed

in version 2.5: This function used an `int` type for *size*. This might require changes in your code for properly supporting 64-bit systems.

void **PyObject\_Del** (PyObject \*op)

Releases memory allocated to an object using `PyObject_New()` or `PyObject_NewVar()`. This is normally called from the `tp_dealloc` handler specified in the object's type. The fields of the object should not be accessed after this call as the memory is no longer a valid Python object.

PyObject\* **Py\_InitModule** (char \*name, PyMethodDef \*methods)

*Return value:* Borrowed reference.

Create a new module object based on a name and table of functions, returning the new module object. Changed in version 2.3: Older versions of Python did not support `NULL` as the value for the *methods* argument.

PyObject\* **Py\_InitModule3** (char \*name, PyMethodDef \*methods, char \*doc)

*Return value:* Borrowed reference.

Create a new module object based on a name and table of functions, returning the new module object. If *doc* is non-`NULL`, it will be used to define the docstring for the module. Changed in version 2.3: Older versions of Python did not support `NULL` as the value for the *methods* argument.

PyObject\* **Py\_InitModule4** (char \*name, PyMethodDef \*methods, char \*doc, PyObject \*self, int apiver)

*Return value:* Borrowed reference.

Create a new module object based on a name and table of functions, returning the new module object. If *doc* is non-`NULL`, it will be used to define the docstring for the module. If *self* is non-`NULL`, it will be passed to the functions of the module as their (otherwise `NULL`) first parameter. (This was added as an experimental feature, and there are no known uses in the current version of Python.) For *apiver*, the only value which should be passed is defined by the constant `PYTHON_API_VERSION`.

---

**Note:** Most uses of this function should probably be using the `Py_InitModule3()` instead; only use this if you are sure you need it.

---

Changed in version 2.3: Older versions of Python did not support `NULL` as the value for the *methods* argument.

PyObject **\_Py\_NoneStruct**

Object which is visible in Python as `None`. This should only be accessed using the `Py_None` macro, which evaluates to a pointer to this object.

## 10.2 Common Object Structures

There are a large number of structures which are used in the definition of object types for Python. This section describes these structures and how they are used.

All Python objects ultimately share a small number of fields at the beginning of the object's representation in memory. These are represented by the `PyObject` and `PyVarObject` types, which are defined, in turn, by the expansions of some macros also used, whether directly or indirectly, in the definition of all other Python objects.

### PyObject

All object types are extensions of this type. This is a type which contains the information Python needs to treat a pointer to an object as an object. In a normal "release" build, it contains only the object's reference count and a pointer to the corresponding type object. It corresponds to the fields defined by the expansion of the `PyObject_HEAD` macro.

### PyVarObject

This is an extension of `PyObject` that adds the `ob_size` field. This is only used for objects that have some notion of *length*. This type does not often appear in the Python/C API. It corresponds to the fields defined by the expansion of the `PyObject_VAR_HEAD` macro.

These macros are used in the definition of `PyObject` and `PyVarObject`:

### **PyObject\_HEAD**

This is a macro which expands to the declarations of the fields of the `PyObject` type; it is used when declaring new types which represent objects without a varying length. The specific fields it expands to depend on the definition of `Py_TRACE_REFS`. By default, that macro is not defined, and `PyObject_HEAD` expands to:

```
Py_ssize_t ob_refcnt;
PyTypeObject *ob_type;
```

When `Py_TRACE_REFS` is defined, it expands to:

```
PyObject *_ob_next, *_ob_prev;
Py_ssize_t ob_refcnt;
PyTypeObject *ob_type;
```

### **PyObject\_VAR\_HEAD**

This is a macro which expands to the declarations of the fields of the `PyVarObject` type; it is used when declaring new types which represent objects with a length that varies from instance to instance. This macro always expands to:

```
PyObject_HEAD
Py_ssize_t ob_size;
```

Note that `PyObject_HEAD` is part of the expansion, and that its own expansion varies depending on the definition of `Py_TRACE_REFS`.

### **PyObject\_HEAD\_INIT (type)**

This is a macro which expands to initialization values for a new `PyObject` type. This macro expands to:

```
_PyObject_EXTRA_INIT
1, type,
```

### **PyVarObject\_HEAD\_INIT (type, size)**

This is a macro which expands to initialization values for a new `PyVarObject` type, including the `ob_size` field. This macro expands to:

```
_PyObject_EXTRA_INIT
1, type, size,
```

### **PyCFunction**

Type of the functions used to implement most Python callables in C. Functions of this type take two `PyObject*` parameters and return one such value. If the return value is `NULL`, an exception shall have been set. If not `NULL`, the return value is interpreted as the return value of the function as exposed in Python. The function must return a new reference.

### **PyMethodDef**

Structure used to describe a method of an extension type. This structure has four fields:

| Field                 | C Type                   | Meaning                                                 |
|-----------------------|--------------------------|---------------------------------------------------------|
| <code>ml_name</code>  | <code>char *</code>      | name of the method                                      |
| <code>ml_meth</code>  | <code>PyCFunction</code> | pointer to the C implementation                         |
| <code>ml_flags</code> | <code>int</code>         | flag bits indicating how the call should be constructed |
| <code>ml_doc</code>   | <code>char *</code>      | points to the contents of the docstring                 |

The `ml_meth` is a C function pointer. The functions may be of different types, but they always return `PyObject*`. If the function is not of the `PyCFunction`, the compiler will require a cast in the method table. Even though `PyCFunction` defines the first parameter as `PyObject*`, it is common that the method implementation uses a the specific C type of the *self* object.

The `ml_flags` field is a bitfield which can include the following flags. The individual flags indicate either a calling convention or a binding convention. Of the calling convention flags, only `METH_VARARGS` and `METH_KEYWORDS` can be combined (but note that `METH_KEYWORDS` alone is equivalent to `METH_VARARGS | METH_KEYWORDS`). Any of the calling convention flags can be combined with a binding flag.

### **METH\_VARARGS**

This is the typical calling convention, where the methods have the type `PyCFunction`. The function expects two `PyObject*` values. The first one is the *self* object for methods; for module functions, it is the module object. The second parameter (often called *args*) is a tuple object representing all arguments. This parameter is typically processed using `PyArg_ParseTuple()` or `PyArg_UnpackTuple()`.

### **METH\_KEYWORDS**

Methods with these flags must be of type `PyCFunctionWithKeywords`. The function expects three parameters: *self*, *args*, and a dictionary of all the keyword arguments. The flag is typically combined with `METH_VARARGS`, and the parameters are typically processed using `PyArg_ParseTupleAndKeywords()`.

### **METH\_NOARGS**

Methods without parameters don't need to check whether arguments are given if they are listed with the `METH_NOARGS` flag. They need to be of type `PyCFunction`. The first parameter is typically named *self* and will hold a reference to the module or object instance. In all cases the second parameter will be `NULL`.

### **METH\_O**

Methods with a single object argument can be listed with the `METH_O` flag, instead of invoking `PyArg_ParseTuple()` with a "O" argument. They have the type `PyCFunction`, with the *self* parameter, and a `PyObject*` parameter representing the single argument.

### **METH\_OLDARGS**

This calling convention is deprecated. The method must be of type `PyCFunction`. The second argument is `NULL` if no arguments are given, a single object if exactly one argument is given, and a tuple of objects if more than one argument is given. There is no way for a function using this convention to distinguish between a call with multiple arguments and a call with a tuple as the only argument.

These two constants are not used to indicate the calling convention but the binding when use with methods of classes. These may not be used for functions defined for modules. At most one of these flags may be set for any given method.

### **METH\_CLASS**

The method will be passed the type object as the first parameter rather than an instance of the type. This is used to create *class methods*, similar to what is created when using the `classmethod()` built-in function. New in version 2.3.

### **METH\_STATIC**

The method will be passed `NULL` as the first parameter rather than an instance of the type. This is used to create *static methods*, similar to what is created when using the `staticmethod()` built-in function. New in version 2.3.

One other constant controls whether a method is loaded in place of another definition with the same method name.

### **METH\_COEXIST**

The method will be loaded in place of existing definitions. Without `METH_COEXIST`, the default is to skip repeated definitions. Since slot wrappers are loaded before the method table, the existence of a *sq\_contains* slot, for example, would generate a wrapped method named `__contains__()` and preclude the loading of a corresponding `PyCFunction` with the same name. With the flag defined, the `PyCFunction` will be loaded in

place of the wrapper object and will co-exist with the slot. This is helpful because calls to PyCFunctions are optimized more than wrapper object calls. New in version 2.4.

### PyMemberDef

Structure which describes an attribute of a type which corresponds to a C struct member. Its fields are:

| Field  | C Type     | Meaning                                                                    |
|--------|------------|----------------------------------------------------------------------------|
| name   | char *     | name of the member                                                         |
| type   | int        | the type of the member in the C struct                                     |
| offset | Py_ssize_t | the offset in bytes that the member is located on the type's object struct |
| flags  | int        | flag bits indicating if the field should be read-only or writable          |
| doc    | char *     | points to the contents of the docstring                                    |

type can be one of many T\_ macros corresponding to various C types. When the member is accessed in Python, it will be converted to the equivalent Python type.

| Macro name  | C type             |
|-------------|--------------------|
| T_SHORT     | short              |
| T_INT       | int                |
| T_LONG      | long               |
| T_FLOAT     | float              |
| T_DOUBLE    | double             |
| T_STRING    | char *             |
| T_OBJECT    | PyObject *         |
| T_OBJECT_EX | PyObject *         |
| T_CHAR      | char               |
| T_BYTE      | char               |
| T_UBYTE     | unsigned char      |
| T_UINT      | unsigned int       |
| T_USHORT    | unsigned short     |
| T_ULONG     | unsigned long      |
| T_BOOL      | char               |
| T_LONGLONG  | long long          |
| T_ULONGLONG | unsigned long long |
| T_PYSSIZET  | Py_ssize_t         |

T\_OBJECT and T\_OBJECT\_EX differ in that T\_OBJECT returns None if the member is NULL and T\_OBJECT\_EX raises an AttributeError. Try to use T\_OBJECT\_EX over T\_OBJECT because T\_OBJECT\_EX handles use of the del statement on that attribute more correctly than T\_OBJECT.

flags can be 0 for write and read access or READONLY for read-only access. Using T\_STRING for type implies READONLY. Only T\_OBJECT and T\_OBJECT\_EX members can be deleted. (They are set to NULL).

PyObject\* **Py\_FindMethod**(PyMethodDef table[], PyObject \*ob, char \*name)

*Return value:* New reference.

Return a bound method object for an extension type implemented in C. This can be useful in the implementation of a tp\_getattro or tp\_getattr handler that does not use the PyObject\_GenericGetAttr() function.

## 10.3 Type Objects

Perhaps one of the most important structures of the Python object system is the structure that defines a new type: the PyTypeObject structure. Type objects can be handled using any of the PyObject\_\*() or PyType\_\*() functions, but do not offer much that's interesting to most Python applications. These objects are fundamental to how objects behave, so they are very important to the interpreter itself and to any extension module that implements new types.

Type objects are fairly large compared to most of the standard types. The reason for the size is that each type object stores a large number of values, mostly C function pointers, each of which implements a small part of the type's functionality. The fields of the type object are examined in detail in this section. The fields will be described in the order in which they occur in the structure.

Typedefs: unaryfunc, binaryfunc, ternaryfunc, inquiry, coercion, intargfunc, intintargfunc, intobjargproc, intintobjargproc, objobjargproc, destructor, freefunc, printfunc, getattrfunc, getattrofunc, setattrfunc, setattrofunc, cmpfunc, reprfunc, hashfunc

The structure definition for `PyTypeObject` can be found in `Include/object.h`. For convenience of reference, this repeats the definition found there:

```
typedef struct _typeobject {
    PyObject_VAR_HEAD
    char *tp_name; /* For printing, in format "<module>.<name>" */
    int tp_basicsize, tp_itemsize; /* For allocation */

    /* Methods to implement standard operations */

    destructor tp_dealloc;
    printfunc tp_print;
    getattrfunc tp_getattr;
    setattrfunc tp_setattr;
    cmpfunc tp_compare;
    reprfunc tp_repr;

    /* Method suites for standard classes */

    PyNumberMethods *tp_as_number;
    PySequenceMethods *tp_as_sequence;
    PyMappingMethods *tp_as_mapping;

    /* More standard operations (here for binary compatibility) */

    hashfunc tp_hash;
    ternaryfunc tp_call;
    reprfunc tp_str;
    getattrofunc tp_getattro;
    setattrofunc tp_setattro;

    /* Functions to access object as input/output buffer */
    PyBufferProcs *tp_as_buffer;

    /* Flags to define presence of optional/expanded features */
    long tp_flags;

    char *tp_doc; /* Documentation string */

    /* Assigned meaning in release 2.0 */
    /* call function for all accessible objects */
    traverseproc tp_traverse;

    /* delete references to contained objects */
    inquiry tp_clear;
```

```

/* Assigned meaning in release 2.1 */
/* rich comparisons */
richcmpfunc tp_richcompare;

/* weak reference enabler */
long tp_weaklistoffset;

/* Added in release 2.2 */
/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;

/* Attribute descriptor and subclassing stuff */
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
struct _typeobject *tp_base;
PyObject *tp_dict;
descrgetfunc tp_descr_get;
descrsetfunc tp_descr_set;
long tp_dictoffset;
initproc tp_init;
allocfunc tp_alloc;
newfunc tp_new;
freefunc tp_free; /* Low-level free-memory routine */
inquiry tp_is_gc; /* For PyObject_IS_GC */
PyObject *tp_bases;
PyObject *tp_mro; /* method resolution order */
PyObject *tp_cache;
PyObject *tp_subclasses;
PyObject *tp_weaklist;

} PyTypeObject;

```

The type object structure extends the `PyVarObject` structure. The `ob_size` field is used for dynamic types (created by `type_new()`, usually called from a class statement). Note that `PyType_Type` (the metatype) initializes `tp_itemsize`, which means that its instances (i.e. type objects) *must* have the `ob_size` field.

**PyObject\* PyObject.\_ob\_next**

**PyObject\* PyObject.\_ob\_prev**

These fields are only present when the macro `Py_TRACE_REFS` is defined. Their initialization to `NULL` is taken care of by the `PyObject_HEAD_INIT` macro. For statically allocated objects, these fields always remain `NULL`. For dynamically allocated objects, these two fields are used to link the object into a doubly-linked list of *all* live objects on the heap. This could be used for various debugging purposes; currently the only use is to print the objects that are still alive at the end of a run when the environment variable

`PYTHONDUMPREFS` is set.

These fields are not inherited by subtypes.

**Py\_ssize\_t PyObject.ob\_refcnt**

This is the type object's reference count, initialized to 1 by the `PyObject_HEAD_INIT` macro. Note that for statically allocated type objects, the type's instances (objects whose `ob_type` points back to the type) do *not* count as references. But for dynamically allocated type objects, the instances *do* count as references.

This field is not inherited by subtypes. Changed in version 2.5: This field used to be an `int` type. This might require changes in your code for properly supporting 64-bit systems.

**PyObject\*** `PyObject.ob_type`

This is the type's type, in other words its metatype. It is initialized by the argument to the `PyObject_HEAD_INIT` macro, and its value should normally be `&PyType_Type`. However, for dynamically loadable extension modules that must be usable on Windows (at least), the compiler complains that this is not a valid initializer. Therefore, the convention is to pass `NULL` to the `PyObject_HEAD_INIT` macro and to initialize this field explicitly at the start of the module's initialization function, before doing anything else. This is typically done like this:

```
Foo_Type.ob_type = &PyType_Type;
```

This should be done before any instances of the type are created. `PyType_Ready()` checks if `ob_type` is `NULL`, and if so, initializes it: in Python 2.2, it is set to `&PyType_Type`; in Python 2.2.1 and later it is initialized to the `ob_type` field of the base class. `PyType_Ready()` will not change this field if it is non-zero.

In Python 2.2, this field is not inherited by subtypes. In 2.2.1, and in 2.3 and beyond, it is inherited by subtypes.

**Py\_ssize\_t** `PyVarObject.ob_size`

For statically allocated type objects, this should be initialized to zero. For dynamically allocated type objects, this field has a special internal meaning.

This field is not inherited by subtypes.

**char\*** `PyTypeObject.tp_name`

Pointer to a NUL-terminated string containing the name of the type. For types that are accessible as module globals, the string should be the full module name, followed by a dot, followed by the type name; for built-in types, it should be just the type name. If the module is a submodule of a package, the full package name is part of the full module name. For example, a type named `T` defined in module `M` in subpackage `Q` in package `P` should have the `tp_name` initializer `"P.Q.M.T"`.

For dynamically allocated type objects, this should just be the type name, and the module name explicitly stored in the type dict as the value for key `'__module__'`.

For statically allocated type objects, the `tp_name` field should contain a dot. Everything before the last dot is made accessible as the `__module__` attribute, and everything after the last dot is made accessible as the `__name__` attribute.

If no dot is present, the entire `tp_name` field is made accessible as the `__name__` attribute, and the `__module__` attribute is undefined (unless explicitly set in the dictionary, as explained above). This means your type will be impossible to pickle.

This field is not inherited by subtypes.

**Py\_ssize\_t** `PyTypeObject.tp_basicsize`**Py\_ssize\_t** `PyTypeObject.tp_itemsize`

These fields allow calculating the size in bytes of instances of the type.

There are two kinds of types: types with fixed-length instances have a zero `tp_itemsize` field, types with variable-length instances have a non-zero `tp_itemsize` field. For a type with fixed-length instances, all instances have the same size, given in `tp_basicsize`.

For a type with variable-length instances, the instances must have an `ob_size` field, and the instance size is `tp_basicsize` plus `N` times `tp_itemsize`, where `N` is the "length" of the object. The value of `N` is typically stored in the instance's `ob_size` field. There are exceptions: for example, long ints use a negative `ob_size` to indicate a negative number, and `N` is `abs(ob_size)` there. Also, the presence of an `ob_size` field in the instance layout doesn't mean that the instance structure is variable-length (for example, the structure for the list type has fixed-length instances, yet those instances have a meaningful `ob_size` field).

The basic size includes the fields in the instance declared by the macro `PyObject_HEAD` or `PyObject_VAR_HEAD` (whichever is used to declare the instance struct) and this in turn includes the

`_ob_prev` and `_ob_next` fields if they are present. This means that the only correct way to get an initializer for the `tp_basicsize` is to use the `sizeof` operator on the struct used to declare the instance layout. The basic size does not include the GC header size (this is new in Python 2.2; in 2.1 and 2.0, the GC header size was included in `tp_basicsize`).

These fields are inherited separately by subtypes. If the base type has a non-zero `tp_itemsize`, it is generally not safe to set `tp_itemsize` to a different non-zero value in a subtype (though this depends on the implementation of the base type).

A note about alignment: if the variable items require a particular alignment, this should be taken care of by the value of `tp_basicsize`. Example: suppose a type implements an array of `double`. `tp_itemsize` is `sizeof(double)`. It is the programmer's responsibility that `tp_basicsize` is a multiple of `sizeof(double)` (assuming this is the alignment requirement for `double`).

#### destructor `PyTypeObject.tp_dealloc`

A pointer to the instance destructor function. This function must be defined unless the type guarantees that its instances will never be deallocated (as is the case for the singletons `None` and `Ellipsis`).

The destructor function is called by the `Py_DECREF()` and `Py_XDECREF()` macros when the new reference count is zero. At this point, the instance is still in existence, but there are no references to it. The destructor function should free all references which the instance owns, free all memory buffers owned by the instance (using the freeing function corresponding to the allocation function used to allocate the buffer), and finally (as its last action) call the type's `tp_free` function. If the type is not subtypable (doesn't have the `Py_TPFLAGS_BASETYPE` flag bit set), it is permissible to call the object deallocator directly instead of via `tp_free`. The object deallocator should be the one used to allocate the instance; this is normally `PyObject_Del()` if the instance was allocated using `PyObject_New()` or `PyObject_VarNew()`, or `PyObject_GC_Del()` if the instance was allocated using `PyObject_GC_New()` or `PyObject_GC_NewVar()`.

This field is inherited by subtypes.

#### printfunc `PyTypeObject.tp_print`

An optional pointer to the instance print function.

The print function is only called when the instance is printed to a *real* file; when it is printed to a pseudo-file (like a `StringIO` instance), the instance's `tp_repr` or `tp_str` function is called to convert it to a string. These are also called when the type's `tp_print` field is `NULL`. A type should never implement `tp_print` in a way that produces different output than `tp_repr` or `tp_str` would.

The print function is called with the same signature as `PyObject_Print(): int tp_print(PyObject *self, FILE *file, int flags)`. The *self* argument is the instance to be printed. The *file* argument is the stdio file to which it is to be printed. The *flags* argument is composed of flag bits. The only flag bit currently defined is `Py_PRINT_RAW`. When the `Py_PRINT_RAW` flag bit is set, the instance should be printed the same way as `tp_str` would format it; when the `Py_PRINT_RAW` flag bit is clear, the instance should be printed the same way as `tp_repr` would format it. It should return `-1` and set an exception condition when an error occurred during the comparison.

It is possible that the `tp_print` field will be deprecated. In any case, it is recommended not to define `tp_print`, but instead to rely on `tp_repr` and `tp_str` for printing.

This field is inherited by subtypes.

#### getattrfunc `PyTypeObject.tp_getattr`

An optional pointer to the get-attribute-string function.

This field is deprecated. When it is defined, it should point to a function that acts the same as the `tp_getattro` function, but taking a C string instead of a Python string object to give the attribute name. The signature is the same as for `PyObject_GetAttrString()`.

This field is inherited by subtypes together with `tp_getattro`: a subtype inherits both `tp_getattr` and `tp_getattro` from its base type when the subtype's `tp_getattr` and `tp_getattro` are both *NULL*.

setattrfunc **PyTypeObject.tp\_setattr**

An optional pointer to the set-attribute-string function.

This field is deprecated. When it is defined, it should point to a function that acts the same as the `tp_setattro` function, but taking a C string instead of a Python string object to give the attribute name. The signature is the same as for `PyObject_SetAttrString()`.

This field is inherited by subtypes together with `tp_setattro`: a subtype inherits both `tp_setattr` and `tp_setattro` from its base type when the subtype's `tp_setattr` and `tp_setattro` are both *NULL*.

cmpfunc **PyTypeObject.tp\_compare**

An optional pointer to the three-way comparison function.

The signature is the same as for `PyObject_Compare()`. The function should return 1 if *self* greater than *other*, 0 if *self* is equal to *other*, and -1 if *self* less than *other*. It should return -1 and set an exception condition when an error occurred during the comparison.

This field is inherited by subtypes together with `tp_richcompare` and `tp_hash`: a subtypes inherits all three of `tp_compare`, `tp_richcompare`, and `tp_hash` when the subtype's `tp_compare`, `tp_richcompare`, and `tp_hash` are all *NULL*.

reprfunc **PyTypeObject.tp\_repr**

An optional pointer to a function that implements the built-in function `repr()`.

The signature is the same as for `PyObject_Repr()`; it must return a string or a Unicode object. Ideally, this function should return a string that, when passed to `eval()`, given a suitable environment, returns an object with the same value. If this is not feasible, it should return a string starting with '`<`' and ending with '`>`' from which both the type and the value of the object can be deduced.

When this field is not set, a string of the form `<%s object at %p>` is returned, where `%s` is replaced by the type name, and `%p` by the object's memory address.

This field is inherited by subtypes.

**PyNumberMethods\*** `tp_as_number`

Pointer to an additional structure that contains fields relevant only to objects which implement the number protocol. These fields are documented in *Number Object Structures*.

The `tp_as_number` field is not inherited, but the contained fields are inherited individually.

**PySequenceMethods\*** `tp_as_sequence`

Pointer to an additional structure that contains fields relevant only to objects which implement the sequence protocol. These fields are documented in *Sequence Object Structures*.

The `tp_as_sequence` field is not inherited, but the contained fields are inherited individually.

**PyMappingMethods\*** `tp_as_mapping`

Pointer to an additional structure that contains fields relevant only to objects which implement the mapping protocol. These fields are documented in *Mapping Object Structures*.

The `tp_as_mapping` field is not inherited, but the contained fields are inherited individually.

hashfunc **PyTypeObject.tp\_hash**

An optional pointer to a function that implements the built-in function `hash()`.

The signature is the same as for `PyObject_Hash()`; it must return a C long. The value -1 should not be returned as a normal return value; when an error occurs during the computation of the hash value, the function should set an exception and return -1.

This field can be set explicitly to `PyObject_HashNotImplemented()` to block inheritance of the hash method from a parent type. This is interpreted as the equivalent of `__hash__ = None` at the Python level, causing `isinstance(o, collections.Hashable)` to correctly return `False`. Note that the converse is also true - setting `__hash__ = None` on a class at the Python level will result in the `tp_hash` slot being set to `PyObject_HashNotImplemented()`.

When this field is not set, two possibilities exist: if the `tp_compare` and `tp_richcompare` fields are both `NULL`, a default hash value based on the object's address is returned; otherwise, a `TypeError` is raised.

This field is inherited by subtypes together with `tp_richcompare` and `tp_compare`: a subtype inherits all three of `tp_compare`, `tp_richcompare`, and `tp_hash`, when the subtype's `tp_compare`, `tp_richcompare` and `tp_hash` are all `NULL`.

#### ternaryfunc `PyTypeObject.tp_call`

An optional pointer to a function that implements calling the object. This should be `NULL` if the object is not callable. The signature is the same as for `PyObject_Call()`.

This field is inherited by subtypes.

#### reprfunc `PyTypeObject.tp_str`

An optional pointer to a function that implements the built-in operation `str()`. (Note that `str` is a type now, and `str()` calls the constructor for that type. This constructor calls `PyObject_Str()` to do the actual work, and `PyObject_Str()` will call this handler.)

The signature is the same as for `PyObject_Str()`; it must return a string or a Unicode object. This function should return a “friendly” string representation of the object, as this is the representation that will be used by the print statement.

When this field is not set, `PyObject_Repr()` is called to return a string representation.

This field is inherited by subtypes.

#### getattrfunc `PyTypeObject.tp_getattro`

An optional pointer to the get-attribute function.

The signature is the same as for `PyObject_GetAttr()`. It is usually convenient to set this field to `PyObject_GenericGetAttr()`, which implements the normal way of looking for object attributes.

This field is inherited by subtypes together with `tp_getattr`: a subtype inherits both `tp_getattr` and `tp_getattro` from its base type when the subtype's `tp_getattr` and `tp_getattro` are both `NULL`.

#### setattrfunc `PyTypeObject.tp_setattro`

An optional pointer to the set-attribute function.

The signature is the same as for `PyObject_SetAttr()`. It is usually convenient to set this field to `PyObject_GenericSetAttr()`, which implements the normal way of setting object attributes.

This field is inherited by subtypes together with `tp_setattr`: a subtype inherits both `tp_setattr` and `tp_setattro` from its base type when the subtype's `tp_setattr` and `tp_setattro` are both `NULL`.

#### `PyBufferProcs*` `PyTypeObject.tp_as_buffer`

Pointer to an additional structure that contains fields relevant only to objects which implement the buffer interface. These fields are documented in *Buffer Object Structures*.

The `tp_as_buffer` field is not inherited, but the contained fields are inherited individually.

#### long `PyTypeObject.tp_flags`

This field is a bit mask of various flags. Some flags indicate variant semantics for certain situations; others are used to indicate that certain fields in the type object (or in the extension structures referenced via `tp_as_number`, `tp_as_sequence`, `tp_as_mapping`, and `tp_as_buffer`) that were historically not always present are valid; if such a flag bit is clear, the type fields it guards must not be accessed and must be considered to have a zero or `NULL` value instead.

Inheritance of this field is complicated. Most flag bits are inherited individually, i.e. if the base type has a flag bit set, the subtype inherits this flag bit. The flag bits that pertain to extension structures are strictly inherited if the extension structure is inherited, i.e. the base type's value of the flag bit is copied into the subtype together with a pointer to the extension structure. The `Py_TPFLAGS_HAVE_GC` flag bit is inherited together with the `tp_traverse` and `tp_clear` fields, i.e. if the `Py_TPFLAGS_HAVE_GC` flag bit is clear in the subtype and the `tp_traverse` and `tp_clear` fields in the subtype exist (as indicated by the `Py_TPFLAGS_HAVE_RICHCOMPARE` flag bit) and have `NULL` values.

The following bit masks are currently defined; these can be ORed together using the `|` operator to form the value of the `tp_flags` field. The macro `PyType_HasFeature()` takes a type and a flags value, `tp` and `f`, and checks whether `tp->tp_flags & f` is non-zero.

**Py\_TPFLAGS\_HAVE\_GETCHARBUFFER**

If this bit is set, the `PyBufferProcs` struct referenced by `tp_as_buffer` has the `bf_getcharbuffer` field.

**Py\_TPFLAGS\_HAVE\_SEQUENCE\_IN**

If this bit is set, the `PySequenceMethods` struct referenced by `tp_as_sequence` has the `sq_contains` field.

**Py\_TPFLAGS\_GC**

This bit is obsolete. The bit it used to name is no longer in use. The symbol is now defined as zero.

**Py\_TPFLAGS\_HAVE\_INPLACEOPS**

If this bit is set, the `PySequenceMethods` struct referenced by `tp_as_sequence` and the `PyNumberMethods` structure referenced by `tp_as_number` contain the fields for in-place operators. In particular, this means that the `PyNumberMethods` structure has the fields `nb_inplace_add`, `nb_inplace_subtract`, `nb_inplace_multiply`, `nb_inplace_divide`, `nb_inplace_remainder`, `nb_inplace_power`, `nb_inplace_lshift`, `nb_inplace_rshift`, `nb_inplace_and`, `nb_inplace_xor`, and `nb_inplace_or`; and the `PySequenceMethods` struct has the fields `sq_inplace_concat` and `sq_inplace_repeat`.

**Py\_TPFLAGS\_CHECKTYPES**

If this bit is set, the binary and ternary operations in the `PyNumberMethods` structure referenced by `tp_as_number` accept arguments of arbitrary object types, and do their own type conversions if needed. If this bit is clear, those operations require that all arguments have the current type as their type, and the caller is supposed to perform a coercion operation first. This applies to `nb_add`, `nb_subtract`, `nb_multiply`, `nb_divide`, `nb_remainder`, `nb_divmod`, `nb_power`, `nb_lshift`, `nb_rshift`, `nb_and`, `nb_xor`, and `nb_or`.

**Py\_TPFLAGS\_HAVE\_RICHCOMPARE**

If this bit is set, the type object has the `tp_richcompare` field, as well as the `tp_traverse` and the `tp_clear` fields.

**Py\_TPFLAGS\_HAVE\_WEAKREFS**

If this bit is set, the `tp_weaklistoffset` field is defined. Instances of a type are weakly referenceable if the type's `tp_weaklistoffset` field has a value greater than zero.

**Py\_TPFLAGS\_HAVE\_ITER**

If this bit is set, the type object has the `tp_iter` and `tp_iternext` fields.

**Py\_TPFLAGS\_HAVE\_CLASS**

If this bit is set, the type object has several new fields defined starting in Python 2.2: `tp_methods`, `tp_members`, `tp_getset`, `tp_base`, `tp_dict`, `tp_descr_get`, `tp_descr_set`, `tp_dictoffset`, `tp_init`, `tp_alloc`, `tp_new`, `tp_free`, `tp_is_gc`, `tp_bases`, `tp_mro`, `tp_cache`, `tp_subclasses`, and `tp_weaklist`.

**Py\_TPFLAGS\_HEAPTYPE**

This bit is set when the type object itself is allocated on the heap. In this case, the `ob_type` field of its instances is considered a reference to the type, and the type object is INCREMENTED when a new instance is created, and DECREMENTED when an instance is destroyed (this does not apply to instances of subtypes; only the type referenced by the instance's `ob_type` gets INCREMENTED or DECREMENTED).

#### **Py\_TPFLAGS\_BASETYPE**

This bit is set when the type can be used as the base type of another type. If this bit is clear, the type cannot be subtyped (similar to a “final” class in Java).

#### **Py\_TPFLAGS\_READY**

This bit is set when the type object has been fully initialized by `PyType_Ready()`.

#### **Py\_TPFLAGS\_READYING**

This bit is set while `PyType_Ready()` is in the process of initializing the type object.

#### **Py\_TPFLAGS\_HAVE\_GC**

This bit is set when the object supports garbage collection. If this bit is set, instances must be created using `PyObject_GC_New()` and destroyed using `PyObject_GC_Del()`. More information in section *Supporting Cyclic Garbage Collection*. This bit also implies that the GC-related fields `tp_traverse` and `tp_clear` are present in the type object; but those fields also exist when `Py_TPFLAGS_HAVE_GC` is clear but `Py_TPFLAGS_HAVE_RICHCOMPARE` is set.

#### **Py\_TPFLAGS\_DEFAULT**

This is a bitmask of all the bits that pertain to the existence of certain fields in the type object and its extension structures. Currently, it includes the following bits: `Py_TPFLAGS_HAVE_GETCHARBUFFER`, `Py_TPFLAGS_HAVE_SEQUENCE_IN`, `Py_TPFLAGS_HAVE_INPLACEOPS`, `Py_TPFLAGS_HAVE_RICHCOMPARE`, `Py_TPFLAGS_HAVE_WEAKREFS`, `Py_TPFLAGS_HAVE_ITER`, and `Py_TPFLAGS_HAVE_CLASS`.

#### **char\* PyObject.tp\_doc**

An optional pointer to a NUL-terminated C string giving the docstring for this type object. This is exposed as the `__doc__` attribute on the type and instances of the type.

This field is *not* inherited by subtypes.

The following three fields only exist if the `Py_TPFLAGS_HAVE_RICHCOMPARE` flag bit is set.

#### **traverseproc PyObject.tp\_traverse**

An optional pointer to a traversal function for the garbage collector. This is only used if the `Py_TPFLAGS_HAVE_GC` flag bit is set. More information about Python's garbage collection scheme can be found in section *Supporting Cyclic Garbage Collection*.

The `tp_traverse` pointer is used by the garbage collector to detect reference cycles. A typical implementation of a `tp_traverse` function simply calls `Py_VISIT()` on each of the instance's members that are Python objects. For example, this is function `local_traverse()` from the `thread` extension module:

```
static int
local_traverse(localobject *self, visitproc visit, void *arg)
{
    Py_VISIT(self->args);
    Py_VISIT(self->kw);
    Py_VISIT(self->dict);
    return 0;
}
```

Note that `Py_VISIT()` is called only on those members that can participate in reference cycles. Although there is also a `self->key` member, it can only be `NULL` or a Python string and therefore cannot be part of a reference cycle.

On the other hand, even if you know a member can never be part of a cycle, as a debugging aid you may want to visit it anyway just so the `gc` module's `get_referents()` function will include it.

Note that `Py_VISIT()` requires the `visit` and `arg` parameters to `local_traverse()` to have these specific names; don't name them just anything.

This field is inherited by subtypes together with `tp_clear` and the `Py_TPFLAGS_HAVE_GC` flag bit: the flag bit, `tp_traverse`, and `tp_clear` are all inherited from the base type if they are all zero in the subtype *and* the subtype has the `Py_TPFLAGS_HAVE_RICHCOMPARE` flag bit set.

#### inquiry `PyObject.tp_clear`

An optional pointer to a clear function for the garbage collector. This is only used if the `Py_TPFLAGS_HAVE_GC` flag bit is set.

The `tp_clear` member function is used to break reference cycles in cyclic garbage detected by the garbage collector. Taken together, all `tp_clear` functions in the system must combine to break all reference cycles. This is subtle, and if in any doubt supply a `tp_clear` function. For example, the tuple type does not implement a `tp_clear` function, because it's possible to prove that no reference cycle can be composed entirely of tuples. Therefore the `tp_clear` functions of other types must be sufficient to break any cycle containing a tuple. This isn't immediately obvious, and there's rarely a good reason to avoid implementing `tp_clear`.

Implementations of `tp_clear` should drop the instance's references to those of its members that may be Python objects, and set its pointers to those members to `NULL`, as in the following example:

```
static int
local_clear(localobject *self)
{
    Py_CLEAR(self->key);
    Py_CLEAR(self->args);
    Py_CLEAR(self->kw);
    Py_CLEAR(self->dict);
    return 0;
}
```

The `Py_CLEAR()` macro should be used, because clearing references is delicate: the reference to the contained object must not be decremented until after the pointer to the contained object is set to `NULL`. This is because decrementing the reference count may cause the contained object to become trash, triggering a chain of reclamation activity that may include invoking arbitrary Python code (due to finalizers, or weakref callbacks, associated with the contained object). If it's possible for such code to reference `self` again, it's important that the pointer to the contained object be `NULL` at that time, so that `self` knows the contained object can no longer be used. The `Py_CLEAR()` macro performs the operations in a safe order.

Because the goal of `tp_clear` functions is to break reference cycles, it's not necessary to clear contained objects like Python strings or Python integers, which can't participate in reference cycles. On the other hand, it may be convenient to clear all contained Python objects, and write the type's `tp_dealloc` function to invoke `tp_clear`.

More information about Python's garbage collection scheme can be found in section *Supporting Cyclic Garbage Collection*.

This field is inherited by subtypes together with `tp_traverse` and the `Py_TPFLAGS_HAVE_GC` flag bit: the flag bit, `tp_traverse`, and `tp_clear` are all inherited from the base type if they are all zero in the subtype *and* the subtype has the `Py_TPFLAGS_HAVE_RICHCOMPARE` flag bit set.

#### richcmpfunc `PyObject.tp_richcompare`

An optional pointer to the rich comparison function, whose signature is `PyObject *tp_richcompare(PyObject *a, PyObject *b, int op)`.

The function should return the result of the comparison (usually `Py_True` or `Py_False`). If the comparison is undefined, it must return `Py_NotImplemented`, if another error occurred it must return `NULL` and set an exception condition.

**Note:** If you want to implement a type for which only a limited set of comparisons makes sense (e.g. `==` and `!=`, but not `<` and friends), directly raise `TypeError` in the rich comparison function.

This field is inherited by subtypes together with `tp_compare` and `tp_hash`: a subtype inherits all three of `tp_compare`, `tp_richcompare`, and `tp_hash`, when the subtype's `tp_compare`, `tp_richcompare`, and `tp_hash` are all `NULL`.

The following constants are defined to be used as the third argument for `tp_richcompare` and for `PyObject_RichCompare()`:

| Constant           | Comparison         |
|--------------------|--------------------|
| <code>Py_LT</code> | <code>&lt;</code>  |
| <code>Py_LE</code> | <code>&lt;=</code> |
| <code>Py_EQ</code> | <code>==</code>    |
| <code>Py_NE</code> | <code>!=</code>    |
| <code>Py_GT</code> | <code>&gt;</code>  |
| <code>Py_GE</code> | <code>&gt;=</code> |

The next field only exists if the `Py_TPFLAGS_HAVE_WEAKREFS` flag bit is set.

#### long `PyTypeObject.tp_weaklistoffset`

If the instances of this type are weakly referenceable, this field is greater than zero and contains the offset in the instance structure of the weak reference list head (ignoring the GC header, if present); this offset is used by `PyObject_ClearWeakRefs()` and the `PyWeakref_*()` functions. The instance structure needs to include a field of type `PyObject*` which is initialized to `NULL`.

Do not confuse this field with `tp_weaklist`; that is the list head for weak references to the type object itself.

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype uses a different weak reference list head than the base type. Since the list head is always found via `tp_weaklistoffset`, this should not be a problem.

When a type defined by a class statement has no `__slots__` declaration, and none of its base types are weakly referenceable, the type is made weakly referenceable by adding a weak reference list head slot to the instance layout and setting the `tp_weaklistoffset` of that slot's offset.

When a type's `__slots__` declaration contains a slot named `__weakref__`, that slot becomes the weak reference list head for instances of the type, and the slot's offset is stored in the type's `tp_weaklistoffset`.

When a type's `__slots__` declaration does not contain a slot named `__weakref__`, the type inherits its `tp_weaklistoffset` from its base type.

The next two fields only exist if the `Py_TPFLAGS_HAVE_ITER` flag bit is set.

#### getiterfunc `PyTypeObject.tp_iter`

An optional pointer to a function that returns an iterator for the object. Its presence normally signals that the instances of this type are iterable (although sequences may be iterable without this function, and classic instances always have this function, even if they don't define an `__iter__()` method).

This function has the same signature as `PyObject_GetIter()`.

This field is inherited by subtypes.

#### iternextfunc `PyTypeObject.tp_iternext`

An optional pointer to a function that returns the next item in an iterator. When the iterator is exhausted, it must return `NULL`; a `StopIteration` exception may or may not be set. When another error occurs, it must return

`NULL` too. Its presence normally signals that the instances of this type are iterators (although classic instances always have this function, even if they don't define a `next()` method).

Iterator types should also define the `tp_iter` function, and that function should return the iterator instance itself (not a new iterator instance).

This function has the same signature as `PyIter_Next()`.

This field is inherited by subtypes.

The next fields, up to and including `tp_weaklist`, only exist if the `Py_TPFLAGS_HAVE_CLASS` flag bit is set.

struct `PyMethodDef*` `PyTypeObject.tp_methods`

An optional pointer to a static `NULL`-terminated array of `PyMethodDef` structures, declaring regular methods of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a method descriptor.

This field is not inherited by subtypes (methods are inherited through a different mechanism).

struct `PyMemberDef*` `PyTypeObject.tp_members`

An optional pointer to a static `NULL`-terminated array of `PyMemberDef` structures, declaring regular data members (fields or slots) of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a member descriptor.

This field is not inherited by subtypes (members are inherited through a different mechanism).

struct `PyGetSetDef*` `PyTypeObject.tp_getset`

An optional pointer to a static `NULL`-terminated array of `PyGetSetDef` structures, declaring computed attributes of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a getset descriptor.

This field is not inherited by subtypes (computed attributes are inherited through a different mechanism).

Docs for `PyGetSetDef`:

```
typedef PyObject *(*getter)(PyObject *, void *);
typedef int (*setter)(PyObject *, PyObject *, void *);

typedef struct PyGetSetDef {
    char *name; /* attribute name */
    getter get; /* C function to get the attribute */
    setter set; /* C function to set the attribute */
    char *doc; /* optional doc string */
    void *closure; /* optional additional data for getter and setter */
} PyGetSetDef;
```

`PyObject*` `PyTypeObject.tp_base`

An optional pointer to a base type from which type properties are inherited. At this level, only single inheritance is supported; multiple inheritance require dynamically creating a type object by calling the metatype.

This field is not inherited by subtypes (obviously), but it defaults to `&PyBaseObject_Type` (which to Python programmers is known as the `type` object).

`PyObject*` `PyTypeObject.tp_dict`

The type's dictionary is stored here by `PyType_Ready()`.

This field should normally be initialized to *NULL* before `PyType_Ready` is called; it may also be initialized to a dictionary containing initial attributes for the type. Once `PyType_Ready()` has initialized the type, extra attributes for the type may be added to this dictionary only if they don't correspond to overloaded operations (like `__add__()`).

This field is not inherited by subtypes (though the attributes defined in here are inherited through a different mechanism).

descrgetfunc **`PyTypeObject.tp_descr_get`**

An optional pointer to a “descriptor get” function.

The function signature is

```
PyObject * tp_descr_get(PyObject *self, PyObject *obj, PyObject *type);
```

This field is inherited by subtypes.

descrsetfunc **`PyTypeObject.tp_descr_set`**

An optional pointer to a “descriptor set” function.

The function signature is

```
int tp_descr_set(PyObject *self, PyObject *obj, PyObject *value);
```

This field is inherited by subtypes.

long **`PyTypeObject.tp_dictoffset`**

If the instances of this type have a dictionary containing instance variables, this field is non-zero and contains the offset in the instances of the type of the instance variable dictionary; this offset is used by `PyObject_GenericGetAttr()`.

Do not confuse this field with `tp_dict`; that is the dictionary for attributes of the type object itself.

If the value of this field is greater than zero, it specifies the offset from the start of the instance structure. If the value is less than zero, it specifies the offset from the *end* of the instance structure. A negative offset is more expensive to use, and should only be used when the instance structure contains a variable-length part. This is used for example to add an instance variable dictionary to subtypes of `str` or `tuple`. Note that the `tp_basicsize` field should account for the dictionary added to the end in that case, even though the dictionary is not included in the basic object layout. On a system with a pointer size of 4 bytes, `tp_dictoffset` should be set to `-4` to indicate that the dictionary is at the very end of the structure.

The real dictionary offset in an instance can be computed from a negative `tp_dictoffset` as follows:

```
dictoffset = tp_basicsize + abs(ob_size)*tp_itemsize + tp_dictoffset
if dictoffset is not aligned on sizeof(void*):
    round up to sizeof(void*)
```

where `tp_basicsize`, `tp_itemsize` and `tp_dictoffset` are taken from the type object, and `ob_size` is taken from the instance. The absolute value is taken because long ints use the sign of `ob_size` to store the sign of the number. (There's never a need to do this calculation yourself; it is done for you by `PyObject_GetDictPtr()`.)

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype instances store the dictionary at a difference offset than the base type. Since the dictionary is always found via `tp_dictoffset`, this should not be a problem.

When a type defined by a class statement has no `__slots__` declaration, and none of its base types has an instance variable dictionary, a dictionary slot is added to the instance layout and the `tp_dictoffset` is set to that slot's offset.

When a type defined by a class statement has a `__slots__` declaration, the type inherits its `tp_dictoffset` from its base type.

(Adding a slot named `__dict__` to the `__slots__` declaration does not have the expected effect, it just causes confusion. Maybe this should be added as a feature just like `__weakref__` though.)

### initproc `PyTypeObject.tp_init`

An optional pointer to an instance initialization function.

This function corresponds to the `__init__()` method of classes. Like `__init__()`, it is possible to create an instance without calling `__init__()`, and it is possible to reinitialize an instance by calling its `__init__()` method again.

The function signature is

```
int tp_init(PyObject *self, PyObject *args, PyObject *kwargs)
```

The `self` argument is the instance to be initialized; the `args` and `kwargs` arguments represent positional and keyword arguments of the call to `__init__()`.

The `tp_init` function, if not `NULL`, is called when an instance is created normally by calling its type, after the type's `tp_new` function has returned an instance of the type. If the `tp_new` function returns an instance of some other type that is not a subtype of the original type, no `tp_init` function is called; if `tp_new` returns an instance of a subtype of the original type, the subtype's `tp_init` is called. (VERSION NOTE: described here is what is implemented in Python 2.2.1 and later. In Python 2.2, the `tp_init` of the type of the object returned by `tp_new` was always called, if not `NULL`.)

This field is inherited by subtypes.

### allocfunc `PyTypeObject.tp_alloc`

An optional pointer to an instance allocation function.

The function signature is

```
PyObject *tp_alloc(PyTypeObject *self, Py_ssize_t nitems)
```

The purpose of this function is to separate memory allocation from memory initialization. It should return a pointer to a block of memory of adequate length for the instance, suitably aligned, and initialized to zeros, but with `ob_refcnt` set to 1 and `ob_type` set to the type argument. If the type's `tp_itemsize` is non-zero, the object's `ob_size` field should be initialized to `nitems` and the length of the allocated memory block should be `tp_basicsize + nitems*tp_itemsize`, rounded up to a multiple of `sizeof(void*)`; otherwise, `nitems` is not used and the length of the block should be `tp_basicsize`.

Do not use this function to do any other instance initialization, not even to allocate additional memory; that should be done by `tp_new`.

This field is inherited by static subtypes, but not by dynamic subtypes (subtypes created by a class statement); in the latter, this field is always set to `PyType_GenericAlloc()`, to force a standard heap allocation strategy. That is also the recommended value for statically defined types.

### newfunc `PyTypeObject.tp_new`

An optional pointer to an instance creation function.

If this function is `NULL` for a particular type, that type cannot be called to create new instances; presumably there is some other way to create instances, like a factory function.

The function signature is

```
PyObject *tp_new(PyTypeObject *subtype, PyObject *args, PyObject *kwargs)
```

The subtype argument is the type of the object being created; the *args* and *kwds* arguments represent positional and keyword arguments of the call to the type. Note that subtype doesn't have to equal the type whose `tp_new` function is called; it may be a subtype of that type (but not an unrelated type).

The `tp_new` function should call `subtype->tp_alloc(subtype, nitems)` to allocate space for the object, and then do only as much further initialization as is absolutely necessary. Initialization that can safely be ignored or repeated should be placed in the `tp_init` handler. A good rule of thumb is that for immutable types, all initialization should take place in `tp_new`, while for mutable types, most initialization should be deferred to `tp_init`.

This field is inherited by subtypes, except it is not inherited by static types whose `tp_base` is `NULL` or `&PyBaseObject_Type`. The latter exception is a precaution so that old extension types don't become callable simply by being linked with Python 2.2.

#### destructor `PyTypeObject.tp_free`

An optional pointer to an instance deallocation function.

The signature of this function has changed slightly: in Python 2.2 and 2.2.1, its signature is destructor:

```
void tp_free(PyObject *)
```

In Python 2.3 and beyond, its signature is `freefunc`:

```
void tp_free(void *)
```

The only initializer that is compatible with both versions is `_PyObject_Del`, whose definition has suitably adapted in Python 2.3.

This field is inherited by static subtypes, but not by dynamic subtypes (subtypes created by a class statement); in the latter, this field is set to a deallocator suitable to match `PyType_GenericAlloc()` and the value of the `Py_TPFLAGS_HAVE_GC` flag bit.

#### inquiry `PyTypeObject.tp_is_gc`

An optional pointer to a function called by the garbage collector.

The garbage collector needs to know whether a particular object is collectible or not. Normally, it is sufficient to look at the object's type's `tp_flags` field, and check the `Py_TPFLAGS_HAVE_GC` flag bit. But some types have a mixture of statically and dynamically allocated instances, and the statically allocated instances are not collectible. Such types should define this function; it should return 1 for a collectible instance, and 0 for a non-collectible instance. The signature is

```
int tp_is_gc(PyObject *self)
```

(The only example of this are types themselves. The metatype, `PyType_Type`, defines this function to distinguish between statically and dynamically allocated types.)

This field is inherited by subtypes. (VERSION NOTE: in Python 2.2, it was not inherited. It is inherited in 2.2.1 and later versions.)

#### `PyObject*` `PyTypeObject.tp_bases`

Tuple of base types.

This is set for types created by a class statement. It should be `NULL` for statically defined types.

This field is not inherited.

#### `PyObject*` `PyTypeObject.tp_mro`

Tuple containing the expanded set of base types, starting with the type itself and ending with `object`, in Method Resolution Order.

This field is not inherited; it is calculated fresh by `PyType_Ready()`.

`PyObject*` `PyTypeObject.tp_cache`

Unused. Not inherited. Internal use only.

`PyObject*` `PyTypeObject.tp_subclasses`

List of weak references to subclasses. Not inherited. Internal use only.

`PyObject*` `PyTypeObject.tp_weaklist`

Weak reference list head, for weak references to this type object. Not inherited. Internal use only.

The remaining fields are only defined if the feature test macro `COUNT_ALLOCS` is defined, and are for internal use only. They are documented here for completeness. None of these fields are inherited by subtypes.

`Py_ssize_t` `PyTypeObject.tp_allocs`

Number of allocations.

`Py_ssize_t` `PyTypeObject.tp_frees`

Number of frees.

`Py_ssize_t` `PyTypeObject.tp_maxalloc`

Maximum simultaneously allocated objects.

`PyObject*` `PyTypeObject.tp_next`

Pointer to the next type object with a non-zero `tp_allocs` field.

Also, note that, in a garbage collected Python, `tp_dealloc` may be called from any Python thread, not just the thread which created the object (if the object becomes part of a refcount cycle, that cycle might be collected by a garbage collection on any thread). This is not a problem for Python API calls, since the thread on which `tp_dealloc` is called will own the Global Interpreter Lock (GIL). However, if the object being destroyed in turn destroys objects from some other C or C++ library, care should be taken to ensure that destroying those objects on the thread which called `tp_dealloc` will not violate any assumptions of the library.

## 10.4 Number Object Structures

### `PyNumberMethods`

This structure holds pointers to the functions which an object uses to implement the number protocol. Almost every function below is used by the function of similar name documented in the *Number Protocol* section.

Here is the structure definition:

```
typedef struct {
    binaryfunc nb_add;
    binaryfunc nb_subtract;
    binaryfunc nb_multiply;
    binaryfunc nb_divide;
    binaryfunc nb_remainder;
    binaryfunc nb_divmod;
    ternaryfunc nb_power;
    unaryfunc nb_negative;
    unaryfunc nb_positive;
    unaryfunc nb_absolute;
    inquiry nb_nonzero;          /* Used by PyObject_IsTrue */
    unaryfunc nb_invert;
    binaryfunc nb_lshift;
    binaryfunc nb_rshift;
    binaryfunc nb_and;
```

```

binaryfunc nb_xor;
binaryfunc nb_or;
coercion nb_coerce;      /* Used by the coerce() function */
unaryfunc nb_int;
unaryfunc nb_long;
unaryfunc nb_float;
unaryfunc nb_oct;
unaryfunc nb_hex;

/* Added in release 2.0 */
binaryfunc nb_inplace_add;
binaryfunc nb_inplace_subtract;
binaryfunc nb_inplace_multiply;
binaryfunc nb_inplace_divide;
binaryfunc nb_inplace_remainder;
ternaryfunc nb_inplace_power;
binaryfunc nb_inplace_lshift;
binaryfunc nb_inplace_rshift;
binaryfunc nb_inplace_and;
binaryfunc nb_inplace_xor;
binaryfunc nb_inplace_or;

/* Added in release 2.2 */
binaryfunc nb_floor_divide;
binaryfunc nb_true_divide;
binaryfunc nb_inplace_floor_divide;
binaryfunc nb_inplace_true_divide;

/* Added in release 2.5 */
unaryfunc nb_index;
} PyNumberMethods;

```

Binary and ternary functions may receive different kinds of arguments, depending on the flag bit `Py_TPFLAGS_CHECKTYPES`:

- If `Py_TPFLAGS_CHECKTYPES` is not set, the function arguments are guaranteed to be of the object's type; the caller is responsible for calling the coercion method specified by the `nb_coerce` member to convert the arguments:

coercion **PyNumberMethods.nb\_coerce**

This function is used by `PyNumber_CoerceEx()` and has the same signature. The first argument is always a pointer to an object of the defined type. If the conversion to a common “larger” type is possible, the function replaces the pointers with new references to the converted objects and returns 0. If the conversion is not possible, the function returns 1. If an error condition is set, it will return -1.

- If the `Py_TPFLAGS_CHECKTYPES` flag is set, binary and ternary functions must check the type of all their operands, and implement the necessary conversions (at least one of the operands is an instance of the defined type). This is the recommended way; with Python 3 coercion will disappear completely.

If the operation is not defined for the given operands, binary and ternary functions must return `Py_NotImplemented`, if another error occurred they must return `NULL` and set an exception.

## 10.5 Mapping Object Structures

### **PyMappingMethods**

This structure holds pointers to the functions which an object uses to implement the mapping protocol. It has three members:

lenfunc **PyMappingMethods.mp\_length**

This function is used by `PyMapping_Length()` and `PyObject_Size()`, and has the same signature. This slot may be set to `NULL` if the object has no defined length.

binaryfunc **PyMappingMethods.mp\_subscript**

This function is used by `PyObject_GetItem()` and has the same signature. This slot must be filled for the `PyMapping_Check()` function to return 1, it can be `NULL` otherwise.

objobjargproc **PyMappingMethods.mp\_ass\_subscript**

This function is used by `PyObject_SetItem()` and has the same signature. If this slot is `NULL`, the object does not support item assignment.

## 10.6 Sequence Object Structures

### **PySequenceMethods**

This structure holds pointers to the functions which an object uses to implement the sequence protocol.

lenfunc **PySequenceMethods.sq\_length**

This function is used by `PySequence_Size()` and `PyObject_Size()`, and has the same signature.

binaryfunc **PySequenceMethods.sq\_concat**

This function is used by `PySequence_Concat()` and has the same signature. It is also used by the `+` operator, after trying the numeric addition via the `tp_as_number.nb_add` slot.

ssizeargfunc **PySequenceMethods.sq\_repeat**

This function is used by `PySequence_Repeat()` and has the same signature. It is also used by the `*` operator, after trying numeric multiplication via the `tp_as_number.nb_mul` slot.

ssizeargfunc **PySequenceMethods.sq\_item**

This function is used by `PySequence_GetItem()` and has the same signature. This slot must be filled for the `PySequence_Check()` function to return 1, it can be `NULL` otherwise.

Negative indexes are handled as follows: if the `sq_length` slot is filled, it is called and the sequence length is used to compute a positive index which is passed to `sq_item`. If `sq_length` is `NULL`, the index is passed as is to the function.

ssizeobjargproc **PySequenceMethods.sq\_ass\_item**

This function is used by `PySequence_SetItem()` and has the same signature. This slot may be left to `NULL` if the object does not support item assignment.

objobjproc **PySequenceMethods.sq\_contains**

This function may be used by `PySequence_Contains()` and has the same signature. This slot may be left to `NULL`, in this case `PySequence_Contains()` simply traverses the sequence until it finds a match.

binaryfunc **PySequenceMethods.sq\_inplace\_concat**

This function is used by `PySequence_InPlaceConcat()` and has the same signature. It should modify its first operand, and return it.

ssizeargfunc **PySequenceMethods.sq\_inplace\_repeat**

This function is used by `PySequence_InPlaceRepeat()` and has the same signature. It should modify its first operand, and return it.

## 10.7 Buffer Object Structures

The buffer interface exports a model where an object can expose its internal data as a set of chunks of data, where each chunk is specified as a pointer/length pair. These chunks are called *segments* and are presumed to be non-contiguous in memory.

If an object does not export the buffer interface, then its `tp_as_buffer` member in the `PyTypeObject` structure should be `NULL`. Otherwise, the `tp_as_buffer` will point to a `PyBufferProcs` structure.

---

**Note:** It is very important that your `PyTypeObject` structure uses `Py_TPFLAGS_DEFAULT` for the value of the `tp_flags` member rather than 0. This tells the Python runtime that your `PyBufferProcs` structure contains the `bf_getcharbuffer` slot. Older versions of Python did not have this member, so a new Python interpreter using an old extension needs to be able to test for its presence before using it.

---

### PyBufferProcs

Structure used to hold the function pointers which define an implementation of the buffer protocol.

The first slot is `bf_getreadbuffer`, of type `getreadbufferproc`. If this slot is `NULL`, then the object does not support reading from the internal data. This is non-sensical, so implementors should fill this in, but callers should test that the slot contains a non-`NULL` value.

The next slot is `bf_getwritebuffer` having type `getwritebufferproc`. This slot may be `NULL` if the object does not allow writing into its returned buffers.

The third slot is `bf_getsegcount`, with type `getsegcountproc`. This slot must not be `NULL` and is used to inform the caller how many segments the object contains. Simple objects such as `PyString_Type` and `PyBuffer_Type` objects contain a single segment.

The last slot is `bf_getcharbuffer`, of type `getcharbufferproc`. This slot will only be present if the `Py_TPFLAGS_HAVE_GETCHARBUFFER` flag is present in the `tp_flags` field of the object's `PyTypeObject`. Before using this slot, the caller should test whether it is present by using the `PyType_HasFeature()` function. If the flag is present, `bf_getcharbuffer` may be `NULL`, indicating that the object's contents cannot be used as *8-bit characters*. The slot function may also raise an error if the object's contents cannot be interpreted as 8-bit characters. For example, if the object is an array which is configured to hold floating point values, an exception may be raised if a caller attempts to use `bf_getcharbuffer` to fetch a sequence of 8-bit characters. This notion of exporting the internal buffers as “text” is used to distinguish between objects that are binary in nature, and those which have character-based content.

---

**Note:** The current policy seems to state that these characters may be multi-byte characters. This implies that a buffer size of  $N$  does not mean there are  $N$  characters present.

---

### Py\_TPFLAGS\_HAVE\_GETCHARBUFFER

Flag bit set in the type structure to indicate that the `bf_getcharbuffer` slot is known. This being set does not indicate that the object supports the buffer interface or that the `bf_getcharbuffer` slot is non-`NULL`.

`Py_ssize_t (*readbufferproc) (PyObject *self, Py_ssize_t segment, void **ptrptr)`

Return a pointer to a readable segment of the buffer in `*ptrptr`. This function is allowed to raise an exception, in which case it must return `-1`. The `segment` which is specified must be zero or positive, and strictly less than the number of segments returned by the `bf_getsegcount` slot function. On success, it returns the length of the segment, and sets `*ptrptr` to a pointer to that memory.

`Py_ssize_t (*writebufferproc) (PyObject *self, Py_ssize_t segment, void **ptrptr)`

Return a pointer to a writable memory buffer in `*ptrptr`, and the length of that segment as the function return value. The memory buffer must correspond to buffer segment `segment`. Must return `-1` and set an exception on

error. `TypeError` should be raised if the object only supports read-only buffers, and `SystemError` should be raised when `segment` specifies a segment that doesn't exist.

`Py_ssize_t (*segcountproc) (PyObject *self, Py_ssize_t *lenp)`

Return the number of memory segments which comprise the buffer. If `lenp` is not `NULL`, the implementation must report the sum of the sizes (in bytes) of all segments in `*lenp`. The function cannot fail.

`Py_ssize_t (*charbufferproc) (PyObject *self, Py_ssize_t segment, const char **ptrptr)`

Return the size of the segment `segment` that `ptrptr` is set to. `*ptrptr` is set to the memory buffer. Returns `-1` on error.

## 10.8 Supporting Cyclic Garbage Collection

Python's support for detecting and collecting garbage which involves circular references requires support from object types which are "containers" for other objects which may also be containers. Types which do not store references to other objects, or which only store references to atomic types (such as numbers or strings), do not need to provide any explicit support for garbage collection.

To create a container type, the `tp_flags` field of the type object must include the `Py_TPFLAGS_HAVE_GC` and provide an implementation of the `tp_traverse` handler. If instances of the type are mutable, a `tp_clear` implementation must also be provided.

### `Py_TPFLAGS_HAVE_GC`

Objects with a type with this flag set must conform with the rules documented here. For convenience these objects will be referred to as container objects.

Constructors for container types must conform to two rules:

1. The memory for the object must be allocated using `PyObject_GC_New()` or `PyObject_GC_NewVar()`.
2. Once all the fields which may contain references to other containers are initialized, it must call `PyObject_GC_Track()`.

`TYPE* PyObject_GC_New (TYPE, PyTypeObject *type)`

Analogous to `PyObject_New()` but for container objects with the `Py_TPFLAGS_HAVE_GC` flag set.

`TYPE* PyObject_GC_NewVar (TYPE, PyTypeObject *type, Py_ssize_t size)`

Analogous to `PyObject_NewVar()` but for container objects with the `Py_TPFLAGS_HAVE_GC` flag set. Changed in version 2.5: This function used an `int` type for `size`. This might require changes in your code for properly supporting 64-bit systems.

`TYPE* PyObject_GC_Resize (TYPE, PyVarObject *op, Py_ssize_t newsize)`

Resize an object allocated by `PyObject_NewVar()`. Returns the resized object or `NULL` on failure. Changed in version 2.5: This function used an `int` type for `newsize`. This might require changes in your code for properly supporting 64-bit systems.

`void PyObject_GC_Track (PyObject *op)`

Adds the object `op` to the set of container objects tracked by the collector. The collector can run at unexpected times so objects must be valid while being tracked. This should be called once all the fields followed by the `tp_traverse` handler become valid, usually near the end of the constructor.

`void PyObject_GC_TRACK (PyObject *op)`

A macro version of `PyObject_GC_Track()`. It should not be used for extension modules.

Similarly, the deallocator for the object must conform to a similar pair of rules:

1. Before fields which refer to other containers are invalidated, `PyObject_GC_UnTrack()` must be called.
2. The object's memory must be deallocated using `PyObject_GC_Del()`.

void **PyObject\_GC\_Del** (void \**op*)

Releases memory allocated to an object using `PyObject_GC_New()` or `PyObject_GC_NewVar()`.

void **PyObject\_GC\_UnTrack** (void \**op*)

Remove the object *op* from the set of container objects tracked by the collector. Note that `PyObject_GC_Track()` can be called again on this object to add it back to the set of tracked objects. The deallocator (`tp_dealloc` handler) should call this for the object before any of the fields used by the `tp_traverse` handler become invalid.

void **\_PyObject\_GC\_UNTRACK** (PyObject \**op*)

A macro version of `PyObject_GC_UnTrack()`. It should not be used for extension modules.

The `tp_traverse` handler accepts a function parameter of this type:

int (**\*visitproc**) (PyObject \**object*, void \**arg*)

Type of the visitor function passed to the `tp_traverse` handler. The function should be called with an object to traverse as *object* and the third parameter to the `tp_traverse` handler as *arg*. The Python core uses several visitor functions to implement cyclic garbage detection; it's not expected that users will need to write their own visitor functions.

The `tp_traverse` handler must have the following type:

int (**\*traverseproc**) (PyObject \**self*, visitproc *visit*, void \**arg*)

Traversal function for a container object. Implementations must call the *visit* function for each object directly contained by *self*, with the parameters to *visit* being the contained object and the *arg* value passed to the handler. The *visit* function must not be called with a `NULL` object argument. If *visit* returns a non-zero value that value should be returned immediately.

To simplify writing `tp_traverse` handlers, a `Py_VISIT()` macro is provided. In order to use this macro, the `tp_traverse` implementation must name its arguments exactly *visit* and *arg*:

void **Py\_VISIT** (PyObject \**o*)

Call the *visit* callback, with arguments *o* and *arg*. If *visit* returns a non-zero value, then return it. Using this macro, `tp_traverse` handlers look like:

```
static int
my_traverse (Noddy *self, visitproc visit, void *arg)
{
    Py_VISIT (self->foo);
    Py_VISIT (self->bar);
    return 0;
}
```

New in version 2.4.

The `tp_clear` handler must be of the `inquiry` type, or `NULL` if the object is immutable.

int (**\*inquiry**) (PyObject \**self*)

Drop references that may have created reference cycles. Immutable objects do not have to define this method since they can never directly create reference cycles. Note that the object must still be valid after calling this method (don't just call `Py_DECREF()` on a reference). The collector will call this method if it detects that this object is involved in a reference cycle.



---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**. . .** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This “intermediate language” is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))      # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator’s `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing “`import this`” at the interactive prompt.

# ABOUT THESE DOCUMENTS

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- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

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|----------------|--------------|-----------|------------|-----------------|
| 0.9.0 thru 1.2 | n/a          | 1991-1995 | CWI        | yes             |
| 1.3 thru 1.5.2 | 1.2          | 1995-1999 | CNRI       | yes             |
| 1.6            | 1.5.2        | 2000      | CNRI       | no              |
| 2.0            | 1.6          | 2000      | BeOpen.com | no              |
| 1.6.1          | 1.6          | 2001      | CNRI       | no              |
| 2.1            | 2.0+1.6.1    | 2001      | PSF        | no              |
| 2.0.1          | 2.0+1.6.1    | 2001      | PSF        | yes             |
| 2.1.1          | 2.1+2.0.1    | 2001      | PSF        | yes             |
| 2.2            | 2.1.1        | 2001      | PSF        | yes             |
| 2.1.2          | 2.1.1        | 2002      | PSF        | yes             |
| 2.1.3          | 2.1.2        | 2002      | PSF        | yes             |
| 2.2.1          | 2.2          | 2002      | PSF        | yes             |
| 2.2.2          | 2.2.1        | 2002      | PSF        | yes             |
| 2.2.3          | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3            | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3.1          | 2.3          | 2002-2003 | PSF        | yes             |
| 2.3.2          | 2.3.1        | 2003      | PSF        | yes             |
| 2.3.3          | 2.3.2        | 2003      | PSF        | yes             |
| 2.3.4          | 2.3.3        | 2004      | PSF        | yes             |
| 2.3.5          | 2.3.4        | 2005      | PSF        | yes             |
| 2.4            | 2.3          | 2004      | PSF        | yes             |

Continued on next page

Table C.1 – continued from previous page

|       |       |      |     |     |
|-------|-------|------|-----|-----|
| 2.4.1 | 2.4   | 2005 | PSF | yes |
| 2.4.2 | 2.4.1 | 2005 | PSF | yes |
| 2.4.3 | 2.4.2 | 2006 | PSF | yes |
| 2.4.4 | 2.4.3 | 2006 | PSF | yes |
| 2.5   | 2.4   | 2006 | PSF | yes |
| 2.5.1 | 2.5   | 2007 | PSF | yes |
| 2.5.2 | 2.5.1 | 2008 | PSF | yes |
| 2.5.3 | 2.5.2 | 2008 | PSF | yes |
| 2.6   | 2.5   | 2008 | PSF | yes |
| 2.6.1 | 2.6   | 2008 | PSF | yes |
| 2.6.2 | 2.6.1 | 2009 | PSF | yes |
| 2.6.3 | 2.6.2 | 2009 | PSF | yes |
| 2.6.4 | 2.6.3 | 2010 | PSF | yes |
| 2.7   | 2.6   | 2010 | PSF | yes |

---

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

```
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```

```
Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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-----
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### C.3.4 MD5 message digest algorithm

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
(section A.5) but excluding the rest of Appendix A. It does not include
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copyrighted.
```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
references to Ghostscript; clarified derivation from RFC 1321;
now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

### **C.3.5 Asynchronous socket services**

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```

```
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http://zooko.com/  
mailto:zooko@zooko.com
```

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Modified by Jack Jansen, CWI, July 1995:

- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

### C.3.9 XML Remote Procedure Calls

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### C.3.10 `test_epoll`

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### C.3.12 strtod and dtoa

The file `Python/dtoa.c`, which supplies C functions `dtoa` and `strtod` for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from <http://www.netlib.org/fp/>. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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# Distributing Python Modules

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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**Authors** Greg Ward, Anthony Baxter

**Email** [distutils-sig@python.org](mailto:distutils-sig@python.org)

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This document describes the Python Distribution Utilities (“Distutils”) from the module developer’s point of view, describing how to use the Distutils to make Python modules and extensions easily available to a wider audience with very little overhead for build/release/install mechanics.



# AN INTRODUCTION TO DISTUTILS

This document covers using the Distutils to distribute your Python modules, concentrating on the role of developer/distributor: if you're looking for information on installing Python modules, you should refer to the *install-index* chapter.

## 1.1 Concepts & Terminology

Using the Distutils is quite simple, both for module developers and for users/administrators installing third-party modules. As a developer, your responsibilities (apart from writing solid, well-documented and well-tested code, of course!) are:

- write a setup script (`setup.py` by convention)
- (optional) write a setup configuration file
- create a source distribution
- (optional) create one or more built (binary) distributions

Each of these tasks is covered in this document.

Not all module developers have access to a multitude of platforms, so it's not always feasible to expect them to create a multitude of built distributions. It is hoped that a class of intermediaries, called *packagers*, will arise to address this need. Packagers will take source distributions released by module developers, build them on one or more platforms, and release the resulting built distributions. Thus, users on the most popular platforms will be able to install most popular Python module distributions in the most natural way for their platform, without having to run a single setup script or compile a line of code.

## 1.2 A Simple Example

The setup script is usually quite simple, although since it's written in Python, there are no arbitrary limits to what you can do with it, though you should be careful about putting arbitrarily expensive operations in your setup script. Unlike, say, Autoconf-style configure scripts, the setup script may be run multiple times in the course of building and installing your module distribution.

If all you want to do is distribute a module called `foo`, contained in a file `foo.py`, then your setup script can be as simple as this:

```
from distutils.core import setup
setup(name='foo',
      version='1.0',
```

```
py_modules=['foo'],
)
```

Some observations:

- most information that you supply to the Distutils is supplied as keyword arguments to the `setup()` function
- those keyword arguments fall into two categories: package metadata (name, version number) and information about what's in the package (a list of pure Python modules, in this case)
- modules are specified by module name, not filename (the same will hold true for packages and extensions)
- it's recommended that you supply a little more metadata, in particular your name, email address and a URL for the project (see section *Writing the Setup Script* for an example)

To create a source distribution for this module, you would create a setup script, `setup.py`, containing the above code, and run this command from a terminal:

```
python setup.py sdist
```

For Windows, open a command prompt windows (*Start* → *Accessories*) and change the command to:

```
setup.py sdist
```

**sdist** will create an archive file (e.g., tarball on Unix, ZIP file on Windows) containing your setup script `setup.py`, and your module `foo.py`. The archive file will be named `foo-1.0.tar.gz` (or `.zip`), and will unpack into a directory `foo-1.0`.

If an end-user wishes to install your `foo` module, all she has to do is download `foo-1.0.tar.gz` (or `.zip`), unpack it, and—from the `foo-1.0` directory—run

```
python setup.py install
```

which will ultimately copy `foo.py` to the appropriate directory for third-party modules in their Python installation.

This simple example demonstrates some fundamental concepts of the Distutils. First, both developers and installers have the same basic user interface, i.e. the setup script. The difference is which Distutils *commands* they use: the **sdist** command is almost exclusively for module developers, while **install** is more often for installers (although most developers will want to install their own code occasionally).

If you want to make things really easy for your users, you can create one or more built distributions for them. For instance, if you are running on a Windows machine, and want to make things easy for other Windows users, you can create an executable installer (the most appropriate type of built distribution for this platform) with the **bdist\_wininst** command. For example:

```
python setup.py bdist_wininst
```

will create an executable installer, `foo-1.0.win32.exe`, in the current directory.

Other useful built distribution formats are RPM, implemented by the **bdist\_rpm** command, Solaris **pkgtool** (**bdist\_pkgtool**), and HP-UX **swinstall** (**bdist\_sdux**). For example, the following command will create an RPM file called `foo-1.0.noarch.rpm`:

```
python setup.py bdist_rpm
```

(The **bdist\_rpm** command uses the **rpm** executable, therefore this has to be run on an RPM-based system such as Red Hat Linux, SuSE Linux, or Mandrake Linux.)

You can find out what distribution formats are available at any time by running

```
python setup.py bdist --help-formats
```

## 1.3 General Python terminology

If you're reading this document, you probably have a good idea of what modules, extensions, and so forth are. Nevertheless, just to be sure that everyone is operating from a common starting point, we offer the following glossary of common Python terms:

**module** the basic unit of code reusability in Python: a block of code imported by some other code. Three types of modules concern us here: pure Python modules, extension modules, and packages.

**pure Python module** a module written in Python and contained in a single `.py` file (and possibly associated `.pyc` and/or `.pyo` files). Sometimes referred to as a “pure module.”

**extension module** a module written in the low-level language of the Python implementation: C/C++ for Python, Java for Jython. Typically contained in a single dynamically loadable pre-compiled file, e.g. a shared object (`.so`) file for Python extensions on Unix, a DLL (given the `.pyd` extension) for Python extensions on Windows, or a Java class file for Jython extensions. (Note that currently, the Distutils only handles C/C++ extensions for Python.)

**package** a module that contains other modules; typically contained in a directory in the filesystem and distinguished from other directories by the presence of a file `__init__.py`.

**root package** the root of the hierarchy of packages. (This isn't really a package, since it doesn't have an `__init__.py` file. But we have to call it something.) The vast majority of the standard library is in the root package, as are many small, standalone third-party modules that don't belong to a larger module collection. Unlike regular packages, modules in the root package can be found in many directories: in fact, every directory listed in `sys.path` contributes modules to the root package.

## 1.4 Distutils-specific terminology

The following terms apply more specifically to the domain of distributing Python modules using the Distutils:

**module distribution** a collection of Python modules distributed together as a single downloadable resource and meant to be installed *en masse*. Examples of some well-known module distributions are Numeric Python, PyXML, PIL (the Python Imaging Library), or mxBase. (This would be called a *package*, except that term is already taken in the Python context: a single module distribution may contain zero, one, or many Python packages.)

**pure module distribution** a module distribution that contains only pure Python modules and packages. Sometimes referred to as a “pure distribution.”

**non-pure module distribution** a module distribution that contains at least one extension module. Sometimes referred to as a “non-pure distribution.”

**distribution root** the top-level directory of your source tree (or source distribution); the directory where `setup.py` exists. Generally `setup.py` will be run from this directory.



# WRITING THE SETUP SCRIPT

The setup script is the centre of all activity in building, distributing, and installing modules using the Distutils. The main purpose of the setup script is to describe your module distribution to the Distutils, so that the various commands that operate on your modules do the right thing. As we saw in section *A Simple Example* above, the setup script consists mainly of a call to `setup()`, and most information supplied to the Distutils by the module developer is supplied as keyword arguments to `setup()`.

Here's a slightly more involved example, which we'll follow for the next couple of sections: the Distutils' own setup script. (Keep in mind that although the Distutils are included with Python 1.6 and later, they also have an independent existence so that Python 1.5.2 users can use them to install other module distributions. The Distutils' own setup script, shown here, is used to install the package into Python 1.5.2.)

```
#!/usr/bin/env python

from distutils.core import setup

setup(name='Distutils',
      version='1.0',
      description='Python Distribution Utilities',
      author='Greg Ward',
      author_email='gward@python.net',
      url='http://www.python.org/sigs/distutils-sig/',
      packages=['distutils', 'distutils.command'],
    )
```

There are only two differences between this and the trivial one-file distribution presented in section *A Simple Example*: more metadata, and the specification of pure Python modules by package, rather than by module. This is important since the Distutils consist of a couple of dozen modules split into (so far) two packages; an explicit list of every module would be tedious to generate and difficult to maintain. For more information on the additional meta-data, see section *Additional meta-data*.

Note that any pathnames (files or directories) supplied in the setup script should be written using the Unix convention, i.e. slash-separated. The Distutils will take care of converting this platform-neutral representation into whatever is appropriate on your current platform before actually using the pathname. This makes your setup script portable across operating systems, which of course is one of the major goals of the Distutils. In this spirit, all pathnames in this document are slash-separated.

This, of course, only applies to pathnames given to Distutils functions. If you, for example, use standard Python functions such as `glob.glob()` or `os.listdir()` to specify files, you should be careful to write portable code instead of hardcoding path separators:

```
glob.glob(os.path.join('mydir', 'subdir', '*.html'))
os.listdir(os.path.join('mydir', 'subdir'))
```

## 2.1 Listing whole packages

The `packages` option tells the Distutils to process (build, distribute, install, etc.) all pure Python modules found in each package mentioned in the `packages` list. In order to do this, of course, there has to be a correspondence between package names and directories in the filesystem. The default correspondence is the most obvious one, i.e. package `distutils` is found in the directory `distutils` relative to the distribution root. Thus, when you say `packages = ['foo']` in your setup script, you are promising that the Distutils will find a file `foo/__init__.py` (which might be spelled differently on your system, but you get the idea) relative to the directory where your setup script lives. If you break this promise, the Distutils will issue a warning but still process the broken package anyway.

If you use a different convention to lay out your source directory, that's no problem: you just have to supply the `package_dir` option to tell the Distutils about your convention. For example, say you keep all Python source under `lib`, so that modules in the “root package” (i.e., not in any package at all) are in `lib`, modules in the `foo` package are in `lib/foo`, and so forth. Then you would put

```
package_dir = {'': 'lib'}
```

in your setup script. The keys to this dictionary are package names, and an empty package name stands for the root package. The values are directory names relative to your distribution root. In this case, when you say `packages = ['foo']`, you are promising that the file `lib/foo/__init__.py` exists.

Another possible convention is to put the `foo` package right in `lib`, the `foo.bar` package in `lib/bar`, etc. This would be written in the setup script as

```
package_dir = {'foo': 'lib'}
```

A package: `dir` entry in the `package_dir` dictionary implicitly applies to all packages below `package`, so the `foo.bar` case is automatically handled here. In this example, having `packages = ['foo', 'foo.bar']` tells the Distutils to look for `lib/__init__.py` and `lib/bar/__init__.py`. (Keep in mind that although `package_dir` applies recursively, you must explicitly list all packages in `packages`: the Distutils will *not* recursively scan your source tree looking for any directory with an `__init__.py` file.)

## 2.2 Listing individual modules

For a small module distribution, you might prefer to list all modules rather than listing packages—especially the case of a single module that goes in the “root package” (i.e., no package at all). This simplest case was shown in section *A Simple Example*; here is a slightly more involved example:

```
py_modules = ['mod1', 'pkg.mod2']
```

This describes two modules, one of them in the “root” package, the other in the `pkg` package. Again, the default package/directory layout implies that these two modules can be found in `mod1.py` and `pkg/mod2.py`, and that `pkg/__init__.py` exists as well. And again, you can override the package/directory correspondence using the `package_dir` option.

## 2.3 Describing extension modules

Just as writing Python extension modules is a bit more complicated than writing pure Python modules, describing them to the Distutils is a bit more complicated. Unlike pure modules, it's not enough just to list modules or packages and expect the Distutils to go out and find the right files; you have to specify the extension name, source file(s), and any compile/link requirements (include directories, libraries to link with, etc.).

All of this is done through another keyword argument to `setup()`, the `ext_modules` option. `ext_modules` is just a list of `Extension` instances, each of which describes a single extension module. Suppose your distribution in-

cludes a single extension, called `foo` and implemented by `foo.c`. If no additional instructions to the compiler/linker are needed, describing this extension is quite simple:

```
Extension('foo', ['foo.c'])
```

The `Extension` class can be imported from `distutils.core` along with `setup()`. Thus, the setup script for a module distribution that contains only this one extension and nothing else might be:

```
from distutils.core import setup, Extension
setup(name='foo',
      version='1.0',
      ext_modules=[Extension('foo', ['foo.c'])],
      )
```

The `Extension` class (actually, the underlying extension-building machinery implemented by the `build_ext` command) supports a great deal of flexibility in describing Python extensions, which is explained in the following sections.

### 2.3.1 Extension names and packages

The first argument to the `Extension` constructor is always the name of the extension, including any package names. For example,

```
Extension('foo', ['src/foo1.c', 'src/foo2.c'])
```

describes an extension that lives in the root package, while

```
Extension('pkg.foo', ['src/foo1.c', 'src/foo2.c'])
```

describes the same extension in the `pkg` package. The source files and resulting object code are identical in both cases; the only difference is where in the filesystem (and therefore where in Python's namespace hierarchy) the resulting extension lives.

If you have a number of extensions all in the same package (or all under the same base package), use the `ext_package` keyword argument to `setup()`. For example,

```
setup(...,
      ext_package='pkg',
      ext_modules=[Extension('foo', ['foo.c']),
                  Extension('subpkg.bar', ['bar.c'])],
      )
```

will compile `foo.c` to the extension `pkg.foo`, and `bar.c` to `pkg.subpkg.bar`.

### 2.3.2 Extension source files

The second argument to the `Extension` constructor is a list of source files. Since the Distutils currently only support C, C++, and Objective-C extensions, these are normally C/C++/Objective-C source files. (Be sure to use appropriate extensions to distinguish C++ source files: `.cc` and `.cpp` seem to be recognized by both Unix and Windows compilers.)

However, you can also include SWIG interface (`.i`) files in the list; the `build_ext` command knows how to deal with SWIG extensions: it will run SWIG on the interface file and compile the resulting C/C++ file into your extension.

This warning notwithstanding, options to SWIG can be currently passed like this:

```
setup(...,
      ext_modules=[Extension('_foo', ['foo.i'],
                            swig_opts=['-modern', '-I../include'])],
      )
```

```
    py_modules=['foo'],  
)
```

Or on the commandline like this:

```
> python setup.py build_ext --swig-opts="-modern -I../include"
```

On some platforms, you can include non-source files that are processed by the compiler and included in your extension. Currently, this just means Windows message text (.mc) files and resource definition (.rc) files for Visual C++. These will be compiled to binary resource (.res) files and linked into the executable.

### 2.3.3 Preprocessor options

Three optional arguments to `Extension` will help if you need to specify include directories to search or preprocessor macros to define/undefine: `include_dirs`, `define_macros`, and `undef_macros`.

For example, if your extension requires header files in the `include` directory under your distribution root, use the `include_dirs` option:

```
Extension('foo', ['foo.c'], include_dirs=['include'])
```

You can specify absolute directories there; if you know that your extension will only be built on Unix systems with X11R6 installed to `/usr`, you can get away with

```
Extension('foo', ['foo.c'], include_dirs=['/usr/include/X11'])
```

You should avoid this sort of non-portable usage if you plan to distribute your code: it's probably better to write C code like

```
#include <X11/Xlib.h>
```

If you need to include header files from some other Python extension, you can take advantage of the fact that header files are installed in a consistent way by the Distutils `install_headers` command. For example, the Numerical Python header files are installed (on a standard Unix installation) to `/usr/local/include/python1.5/Numerical`. (The exact location will differ according to your platform and Python installation.) Since the Python include directory—`/usr/local/include/python1.5` in this case—is always included in the search path when building Python extensions, the best approach is to write C code like

```
#include <Numerical/arrayobject.h>
```

If you must put the Numerical include directory right into your header search path, though, you can find that directory using the Distutils `distutils.sysconfig` module:

```
from distutils.sysconfig import get_python_inc  
includir = os.path.join(get_python_inc(plat_specific=1), 'Numerical')  
setup(...,  
      Extension(..., include_dirs=[includir]),  
      )
```

Even though this is quite portable—it will work on any Python installation, regardless of platform—it's probably easier to just write your C code in the sensible way.

You can define and undefine pre-processor macros with the `define_macros` and `undef_macros` options. `define_macros` takes a list of (name, value) tuples, where name is the name of the macro to define (a string) and value is its value: either a string or None. (Defining a macro `FOO` to None is the equivalent of a bare `#define FOO` in your C source: with most compilers, this sets `FOO` to the string 1.) `undef_macros` is just a list of macros to undefine.

For example:

```
Extension(...,
            define_macros=[('NDEBUG', '1'),
                           ('HAVE_STRFTIME', None)],
            undef_macros=['HAVE_FOO', 'HAVE_BAR'])
```

is the equivalent of having this at the top of every C source file:

```
#define NDEBUG 1
#define HAVE_STRFTIME
#undef HAVE_FOO
#undef HAVE_BAR
```

### 2.3.4 Library options

You can also specify the libraries to link against when building your extension, and the directories to search for those libraries. The `libraries` option is a list of libraries to link against, `library_dirs` is a list of directories to search for libraries at link-time, and `runtime_library_dirs` is a list of directories to search for shared (dynamically loaded) libraries at run-time.

For example, if you need to link against libraries known to be in the standard library search path on target systems

```
Extension(...,
            libraries=['gdbm', 'readline'])
```

If you need to link with libraries in a non-standard location, you'll have to include the location in `library_dirs`:

```
Extension(...,
            library_dirs=['/usr/X11R6/lib'],
            libraries=['X11', 'Xt'])
```

(Again, this sort of non-portable construct should be avoided if you intend to distribute your code.)

### 2.3.5 Other options

There are still some other options which can be used to handle special cases.

The `extra_objects` option is a list of object files to be passed to the linker. These files must not have extensions, as the default extension for the compiler is used.

`extra_compile_args` and `extra_link_args` can be used to specify additional command line options for the respective compiler and linker command lines.

`export_symbols` is only useful on Windows. It can contain a list of symbols (functions or variables) to be exported. This option is not needed when building compiled extensions: Distutils will automatically add `initmodule` to the list of exported symbols.

The `depends` option is a list of files that the extension depends on (for example header files). The build command will call the compiler on the sources to rebuild extension if any on this files has been modified since the previous build.

## 2.4 Relationships between Distributions and Packages

A distribution may relate to packages in three specific ways:

1. It can require packages or modules.
2. It can provide packages or modules.
3. It can obsolete packages or modules.

These relationships can be specified using keyword arguments to the `distutils.core.setup()` function.

Dependencies on other Python modules and packages can be specified by supplying the `requires` keyword argument to `setup()`. The value must be a list of strings. Each string specifies a package that is required, and optionally what versions are sufficient.

To specify that any version of a module or package is required, the string should consist entirely of the module or package name. Examples include `'mymodule'` and `'xml.parsers.expat'`.

If specific versions are required, a sequence of qualifiers can be supplied in parentheses. Each qualifier may consist of a comparison operator and a version number. The accepted comparison operators are:

```
<      >      ==
<=     >=     !=
```

These can be combined by using multiple qualifiers separated by commas (and optional whitespace). In this case, all of the qualifiers must be matched; a logical AND is used to combine the evaluations.

Let's look at a bunch of examples:

| Requires Expression                    | Explanation                                                      |
|----------------------------------------|------------------------------------------------------------------|
| <code>==1.0</code>                     | Only version 1.0 is compatible                                   |
| <code>&gt;1.0, !=1.5.1, &lt;2.0</code> | Any version after 1.0 and before 2.0 is compatible, except 1.5.1 |

Now that we can specify dependencies, we also need to be able to specify what we provide that other distributions can require. This is done using the `provides` keyword argument to `setup()`. The value for this keyword is a list of strings, each of which names a Python module or package, and optionally identifies the version. If the version is not specified, it is assumed to match that of the distribution.

Some examples:

| Provides Expression      | Explanation                                                                    |
|--------------------------|--------------------------------------------------------------------------------|
| <code>mypkg</code>       | Provide <code>mypkg</code> , using the distribution version                    |
| <code>mypkg (1.1)</code> | Provide <code>mypkg</code> version 1.1, regardless of the distribution version |

A package can declare that it obsoletes other packages using the `obsoletes` keyword argument. The value for this is similar to that of the `requires` keyword: a list of strings giving module or package specifiers. Each specifier consists of a module or package name optionally followed by one or more version qualifiers. Version qualifiers are given in parentheses after the module or package name.

The versions identified by the qualifiers are those that are obsoleted by the distribution being described. If no qualifiers are given, all versions of the named module or package are understood to be obsoleted.

## 2.5 Installing Scripts

So far we have been dealing with pure and non-pure Python modules, which are usually not run by themselves but imported by scripts.

Scripts are files containing Python source code, intended to be started from the command line. Scripts don't require Distutils to do anything very complicated. The only clever feature is that if the first line of the script starts with `#!` and contains the word "python", the Distutils will adjust the first line to refer to the current interpreter location. By default, it is replaced with the current interpreter location. The `--executable` (or `-e`) option will allow the interpreter path to be explicitly overridden.

The `scripts` option simply is a list of files to be handled in this way. From the PyXML setup script:

```
setup(...,
      scripts=['scripts/xmlproc_parse', 'scripts/xmlproc_val']
    )
```

Changed in version 2.7: All the scripts will also be added to the MANIFEST file if no template is provided. See *Specifying the files to distribute*.

## 2.6 Installing Package Data

Often, additional files need to be installed into a package. These files are often data that's closely related to the package's implementation, or text files containing documentation that might be of interest to programmers using the package. These files are called *package data*.

Package data can be added to packages using the `package_data` keyword argument to the `setup()` function. The value must be a mapping from package name to a list of relative path names that should be copied into the package. The paths are interpreted as relative to the directory containing the package (information from the `package_dir` mapping is used if appropriate); that is, the files are expected to be part of the package in the source directories. They may contain glob patterns as well.

The path names may contain directory portions; any necessary directories will be created in the installation.

For example, if a package should contain a subdirectory with several data files, the files can be arranged like this in the source tree:

```
setup.py
src/
  mypkg/
    __init__.py
    module.py
    data/
      tables.dat
      spoons.dat
      forks.dat
```

The corresponding call to `setup()` might be:

```
setup(...,
      packages=['mypkg'],
      package_dir={'mypkg': 'src/mypkg'},
      package_data={'mypkg': ['data/*.dat']},
      )
```

New in version 2.4.Changed in version 2.7: All the files that match `package_data` will be added to the MANIFEST file if no template is provided. See *Specifying the files to distribute*.

## 2.7 Installing Additional Files

The `data_files` option can be used to specify additional files needed by the module distribution: configuration files, message catalogs, data files, anything which doesn't fit in the previous categories.

`data_files` specifies a sequence of (*directory, files*) pairs in the following way:

```
setup(...,
      data_files=[('bitmaps', ['bm/b1.gif', 'bm/b2.gif']),
                  ('config', ['cfg/data.cfg']),
                  ('/etc/init.d', ['init-script'])]
      )
```

Note that you can specify the directory names where the data files will be installed, but you cannot rename the data files themselves.

Each (*directory*, *files*) pair in the sequence specifies the installation directory and the files to install there. If *directory* is a relative path, it is interpreted relative to the installation prefix (Python's `sys.prefix` for pure-Python packages, `sys.exec_prefix` for packages that contain extension modules). Each file name in *files* is interpreted relative to the `setup.py` script at the top of the package source distribution. No directory information from *files* is used to determine the final location of the installed file; only the name of the file is used.

You can specify the `data_files` options as a simple sequence of files without specifying a target directory, but this is not recommended, and the `install` command will print a warning in this case. To install data files directly in the target directory, an empty string should be given as the directory. Changed in version 2.7: All the files that match `data_files` will be added to the MANIFEST file if no template is provided. See *Specifying the files to distribute*.

## 2.8 Additional meta-data

The setup script may include additional meta-data beyond the name and version. This information includes:

| Meta-Data                     | Description                                  | Value           | Notes  |
|-------------------------------|----------------------------------------------|-----------------|--------|
| <code>name</code>             | name of the package                          | short string    | (1)    |
| <code>version</code>          | version of this release                      | short string    | (1)(2) |
| <code>author</code>           | package author's name                        | short string    | (3)    |
| <code>author_email</code>     | email address of the package author          | email address   | (3)    |
| <code>maintainer</code>       | package maintainer's name                    | short string    | (3)    |
| <code>maintainer_email</code> | email address of the package maintainer      | email address   | (3)    |
| <code>url</code>              | home page for the package                    | URL             | (1)    |
| <code>description</code>      | short, summary description of the package    | short string    |        |
| <code>long_description</code> | longer description of the package            | long string     | (5)    |
| <code>download_url</code>     | location where the package may be downloaded | URL             | (4)    |
| <code>classifiers</code>      | a list of classifiers                        | list of strings | (4)    |
| <code>platforms</code>        | a list of platforms                          | list of strings |        |
| <code>license</code>          | license for the package                      | short string    | (6)    |

Notes:

1. These fields are required.
2. It is recommended that versions take the form *major.minor[.patch[.sub]]*.
3. Either the author or the maintainer must be identified.
4. These fields should not be used if your package is to be compatible with Python versions prior to 2.2.3 or 2.3. The list is available from the [PyPI website](http://www.python.org/doc/2.3/classifiers/).
5. The `long_description` field is used by PyPI when you are registering a package, to build its home page.
6. The `license` field is a text indicating the license covering the package where the license is not a selection from the "License" Trove classifiers. See the `Classifier` field. Notice that there's a `licence` distribution option which is deprecated but still acts as an alias for `license`.

**'short string'** A single line of text, not more than 200 characters.

**'long string'** Multiple lines of plain text in reStructuredText format (see <http://docutils.sf.net/>).

**'list of strings'** See below.

None of the string values may be Unicode.

Encoding the version information is an art in itself. Python packages generally adhere to the version format *major.minor[.patch][sub]*. The major number is 0 for initial, experimental releases of software. It is incremented for releases that represent major milestones in a package. The minor number is incremented when important new features are added to the package. The patch number increments when bug-fix releases are made. Additional trailing

version information is sometimes used to indicate sub-releases. These are “a1,a2,...,aN” (for alpha releases, where functionality and API may change), “b1,b2,...,bN” (for beta releases, which only fix bugs) and “pr1,pr2,...,prN” (for final pre-release release testing). Some examples:

**0.1.0** the first, experimental release of a package

**1.0.1a2** the second alpha release of the first patch version of 1.0

*classifiers* are specified in a Python list:

```
setup(...,
    classifiers=[
        'Development Status :: 4 - Beta',
        'Environment :: Console',
        'Environment :: Web Environment',
        'Intended Audience :: End Users/Desktop',
        'Intended Audience :: Developers',
        'Intended Audience :: System Administrators',
        'License :: OSI Approved :: Python Software Foundation License',
        'Operating System :: MacOS :: MacOS X',
        'Operating System :: Microsoft :: Windows',
        'Operating System :: POSIX',
        'Programming Language :: Python',
        'Topic :: Communications :: Email',
        'Topic :: Office/Business',
        'Topic :: Software Development :: Bug Tracking',
    ],
)
```

If you wish to include classifiers in your `setup.py` file and also wish to remain backwards-compatible with Python releases prior to 2.2.3, then you can include the following code fragment in your `setup.py` before the `setup()` call.

```
# patch distutils if it can't cope with the "classifiers" or
# "download_url" keywords
from sys import version
if version < '2.2.3':
    from distutils.dist import DistributionMetadata
    DistributionMetadata.classifiers = None
    DistributionMetadata.download_url = None
```

## 2.9 Debugging the setup script

Sometimes things go wrong, and the setup script doesn't do what the developer wants.

Distutils catches any exceptions when running the setup script, and print a simple error message before the script is terminated. The motivation for this behaviour is to not confuse administrators who don't know much about Python and are trying to install a package. If they get a big long traceback from deep inside the guts of Distutils, they may think the package or the Python installation is broken because they don't read all the way down to the bottom and see that it's a permission problem.

On the other hand, this doesn't help the developer to find the cause of the failure. For this purpose, the `DISTUTILS_DEBUG` environment variable can be set to anything except an empty string, and distutils will now print detailed information what it is doing, and prints the full traceback in case an exception occurs.



# WRITING THE SETUP CONFIGURATION FILE

Often, it's not possible to write down everything needed to build a distribution *a priori*: you may need to get some information from the user, or from the user's system, in order to proceed. As long as that information is fairly simple—a list of directories to search for C header files or libraries, for example—then providing a configuration file, `setup.cfg`, for users to edit is a cheap and easy way to solicit it. Configuration files also let you provide default values for any command option, which the installer can then override either on the command-line or by editing the config file.

The setup configuration file is a useful middle-ground between the setup script—which, ideally, would be opaque to installers<sup>1</sup>—and the command-line to the setup script, which is outside of your control and entirely up to the installer. In fact, `setup.cfg` (and any other Distutils configuration files present on the target system) are processed after the contents of the setup script, but before the command-line. This has several useful consequences:

- installers can override some of what you put in `setup.py` by editing `setup.cfg`
- you can provide non-standard defaults for options that are not easily set in `setup.py`
- installers can override anything in `setup.cfg` using the command-line options to `setup.py`

The basic syntax of the configuration file is simple:

```
[command]
option=value
...
```

where *command* is one of the Distutils commands (e.g. **build\_py**, **install**), and *option* is one of the options that command supports. Any number of options can be supplied for each command, and any number of command sections can be included in the file. Blank lines are ignored, as are comments, which run from a '#' character until the end of the line. Long option values can be split across multiple lines simply by indenting the continuation lines.

You can find out the list of options supported by a particular command with the universal `--help` option, e.g.

```
> python setup.py --help build_ext
[...]
Options for 'build_ext' command:
  --build-lib (-b)      directory for compiled extension modules
  --build-temp (-t)     directory for temporary files (build by-products)
  --inplace (-i)        ignore build-lib and put compiled extensions into the
                        source directory alongside your pure Python modules
  --include-dirs (-I)   list of directories to search for header files
  --define (-D)         C preprocessor macros to define
```

---

<sup>1</sup> This ideal probably won't be achieved until auto-configuration is fully supported by the Distutils.

```
--undef (-U)          C preprocessor macros to undefine
--swig-opts          list of SWIG command line options
[...]
```

Note that an option spelled `--foo-bar` on the command-line is spelled `foo_bar` in configuration files.

For example, say you want your extensions to be built “in-place”—that is, you have an extension `pkg.ext`, and you want the compiled extension file (`ext.so` on Unix, say) to be put in the same source directory as your pure Python modules `pkg.mod1` and `pkg.mod2`. You can always use the `--inplace` option on the command-line to ensure this:

```
python setup.py build_ext --inplace
```

But this requires that you always specify the **build\_ext** command explicitly, and remember to provide `--inplace`. An easier way is to “set and forget” this option, by encoding it in `setup.cfg`, the configuration file for this distribution:

```
[build_ext]
inplace=1
```

This will affect all builds of this module distribution, whether or not you explicitly specify **build\_ext**. If you include `setup.cfg` in your source distribution, it will also affect end-user builds—which is probably a bad idea for this option, since always building extensions in-place would break installation of the module distribution. In certain peculiar cases, though, modules are built right in their installation directory, so this is conceivably a useful ability. (Distributing extensions that expect to be built in their installation directory is almost always a bad idea, though.)

Another example: certain commands take a lot of options that don’t change from run to run; for example, **bdist\_rpm** needs to know everything required to generate a “spec” file for creating an RPM distribution. Some of this information comes from the setup script, and some is automatically generated by the Distutils (such as the list of files installed). But some of it has to be supplied as options to **bdist\_rpm**, which would be very tedious to do on the command-line for every run. Hence, here is a snippet from the Distutils’ own `setup.cfg`:

```
[bdist_rpm]
release = 1
packager = Greg Ward <gward@python.net>
doc_files = CHANGES.txt
            README.txt
            USAGE.txt
            doc/
            examples/
```

Note that the `doc_files` option is simply a whitespace-separated string split across multiple lines for readability.

### See Also:

***inst-config-syntax* in “Installing Python Modules”** More information on the configuration files is available in the manual for system administrators.

# CREATING A SOURCE DISTRIBUTION

As shown in section *A Simple Example*, you use the **sdist** command to create a source distribution. In the simplest case,

```
python setup.py sdist
```

(assuming you haven't specified any **sdist** options in the setup script or config file), **sdist** creates the archive of the default format for the current platform. The default format is a gzip'ed tar file (`.tar.gz`) on Unix, and ZIP file on Windows.

You can specify as many formats as you like using the `--formats` option, for example:

```
python setup.py sdist --formats=gztar,zip
```

to create a gzipped tarball and a zip file. The available formats are:

| Format | Description                                 | Notes   |
|--------|---------------------------------------------|---------|
| zip    | zip file ( <code>.zip</code> )              | (1),(3) |
| gztar  | gzip'ed tar file ( <code>.tar.gz</code> )   | (2)     |
| bztar  | bzip2'ed tar file ( <code>.tar.bz2</code> ) |         |
| ztar   | compressed tar file ( <code>.tar.Z</code> ) | (4)     |
| tar    | tar file ( <code>.tar</code> )              |         |

Notes:

1. default on Windows
2. default on Unix
3. requires either external **zip** utility or `zipfile` module (part of the standard Python library since Python 1.6)
4. requires the **compress** program.

When using any `tar` format (`gztar`, `bztar`, `ztar` or `tar`) under Unix, you can specify the owner and group names that will be set for each member of the archive.

For example, if you want all files of the archive to be owned by root:

```
python setup.py sdist --owner=root --group=root
```

## 4.1 Specifying the files to distribute

If you don't supply an explicit list of files (or instructions on how to generate one), the **sdist** command puts a minimal default set into the source distribution:

- all Python source files implied by the `py_modules` and `packages` options

- all C source files mentioned in the `ext_modules` or `libraries` options
- scripts identified by the `scripts` option See *Installing Scripts*.
- anything that looks like a test script: `test/test*.py` (currently, the Distutils don't do anything with test scripts except include them in source distributions, but in the future there will be a standard for testing Python module distributions)
- `README.txt` (or `README`), `setup.py` (or whatever you called your setup script), and `setup.cfg`
- all files that matches the `package_data` metadata. See *Installing Package Data*.
- all files that matches the `data_files` metadata. See *Installing Additional Files*.

Sometimes this is enough, but usually you will want to specify additional files to distribute. The typical way to do this is to write a *manifest template*, called `MANIFEST.in` by default. The manifest template is just a list of instructions for how to generate your manifest file, `MANIFEST`, which is the exact list of files to include in your source distribution. The **sdist** command processes this template and generates a manifest based on its instructions and what it finds in the filesystem.

If you prefer to roll your own manifest file, the format is simple: one filename per line, regular files (or symlinks to them) only. If you do supply your own `MANIFEST`, you must specify everything: the default set of files described above does not apply in this case. Changed in version 2.7: An existing generated `MANIFEST` will be regenerated without **sdist** comparing its modification time to the one of `MANIFEST.in` or `setup.py`. Changed in version 2.7.1: `MANIFEST` files start with a comment indicating they are generated. Files without this comment are not overwritten or removed. Changed in version 2.7.3: **sdist** will read a `MANIFEST` file if no `MANIFEST.in` exists, like it did before 2.7. See *The MANIFEST.in template* section for a syntax reference.

## 4.2 Manifest-related options

The normal course of operations for the **sdist** command is as follows:

- if the manifest file (`MANIFEST` by default) exists and the first line does not have a comment indicating it is generated from `MANIFEST.in`, then it is used as is, unaltered
- if the manifest file doesn't exist or has been previously automatically generated, read `MANIFEST.in` and create the manifest
- if neither `MANIFEST` nor `MANIFEST.in` exist, create a manifest with just the default file set
- use the list of files now in `MANIFEST` (either just generated or read in) to create the source distribution archive(s)

There are a couple of options that modify this behaviour. First, use the `--no-defaults` and `--no-prune` to disable the standard “include” and “exclude” sets.

Second, you might just want to (re)generate the manifest, but not create a source distribution:

```
python setup.py sdist --manifest-only
```

`-o` is a shortcut for `--manifest-only`.

## 4.3 The MANIFEST.in template

A `MANIFEST.in` file can be added in a project to define the list of files to include in the distribution built by the **sdist** command.

When **sdist** is run, it will look for the `MANIFEST.in` file and interpret it to generate the `MANIFEST` file that contains the list of files that will be included in the package.

This mechanism can be used when the default list of files is not enough. (See *Specifying the files to distribute*).

### 4.3.1 Principle

The manifest template has one command per line, where each command specifies a set of files to include or exclude from the source distribution. For an example, let's look at the Distutils' own manifest template:

```
include *.txt
recursive-include examples *.txt *.py
prune examples/sample?/build
```

The meanings should be fairly clear: include all files in the distribution root matching `*.txt`, all files anywhere under the `examples` directory matching `*.txt` or `*.py`, and exclude all directories matching `examples/sample?/build`. All of this is done *after* the standard include set, so you can exclude files from the standard set with explicit instructions in the manifest template. (Or, you can use the `--no-defaults` option to disable the standard set entirely.)

The order of commands in the manifest template matters: initially, we have the list of default files as described above, and each command in the template adds to or removes from that list of files. Once we have fully processed the manifest template, we remove files that should not be included in the source distribution:

- all files in the Distutils “build” tree (default `build/`)
- all files in directories named `RCS`, `CVS`, `.svn`, `.hg`, `.git`, `.bzip` or `_darcs`

Now we have our complete list of files, which is written to the manifest for future reference, and then used to build the source distribution archive(s).

You can disable the default set of included files with the `--no-defaults` option, and you can disable the standard exclude set with `--no-prune`.

Following the Distutils' own manifest template, let's trace how the `sdist` command builds the list of files to include in the Distutils source distribution:

1. include all Python source files in the `distutils` and `distutils/command` subdirectories (because packages corresponding to those two directories were mentioned in the `packages` option in the setup script—see section *Writing the Setup Script*)
2. include `README.txt`, `setup.py`, and `setup.cfg` (standard files)
3. include `test/test*.py` (standard files)
4. include `*.txt` in the distribution root (this will find `README.txt` a second time, but such redundancies are weeded out later)
5. include anything matching `*.txt` or `*.py` in the sub-tree under `examples`,
6. exclude all files in the sub-trees starting at directories matching `examples/sample?/build`—this may exclude files included by the previous two steps, so it's important that the `prune` command in the manifest template comes after the `recursive-include` command
7. exclude the entire `build` tree, and any `RCS`, `CVS`, `.svn`, `.hg`, `.git`, `.bzip` and `_darcs` directories

Just like in the setup script, file and directory names in the manifest template should always be slash-separated; the Distutils will take care of converting them to the standard representation on your platform. That way, the manifest template is portable across operating systems.

### 4.3.2 Commands

The manifest template commands are:

| Command                                    | Description                                                                           |
|--------------------------------------------|---------------------------------------------------------------------------------------|
| <b>include pat1 pat2 ...</b>               | include all files matching any of the listed patterns                                 |
| <b>exclude pat1 pat2 ...</b>               | exclude all files matching any of the listed patterns                                 |
| <b>recursive-include dir pat1 pat2</b>     | include all files under <i>dir</i> matching any of the listed patterns                |
| <b>...</b>                                 |                                                                                       |
| <b>recursive-exclude dir pat1 pat2 ...</b> | exclude all files under <i>dir</i> matching any of the listed patterns                |
| <b>global-include pat1 pat2 ...</b>        | include all files anywhere in the source tree matching — & any of the listed patterns |
| <b>global-exclude pat1 pat2 ...</b>        | exclude all files anywhere in the source tree matching — & any of the listed patterns |
| <b>prune dir</b>                           | exclude all files under <i>dir</i>                                                    |
| <b>graft dir</b>                           | include all files under <i>dir</i>                                                    |

The patterns here are Unix-style “glob” patterns: `*` matches any sequence of regular filename characters, `?` matches any single regular filename character, and `[range]` matches any of the characters in *range* (e.g., `a-z`, `a-zA-Z`, `a-f0-9_.`). The definition of “regular filename character” is platform-specific: on Unix it is anything except slash; on Windows anything except backslash or colon.

# CREATING BUILT DISTRIBUTIONS

A “built distribution” is what you’re probably used to thinking of either as a “binary package” or an “installer” (depending on your background). It’s not necessarily binary, though, because it might contain only Python source code and/or byte-code; and we don’t call it a package, because that word is already spoken for in Python. (And “installer” is a term specific to the world of mainstream desktop systems.)

A built distribution is how you make life as easy as possible for installers of your module distribution: for users of RPM-based Linux systems, it’s a binary RPM; for Windows users, it’s an executable installer; for Debian-based Linux users, it’s a Debian package; and so forth. Obviously, no one person will be able to create built distributions for every platform under the sun, so the Distutils are designed to enable module developers to concentrate on their specialty—writing code and creating source distributions—while an intermediary species called *packagers* springs up to turn source distributions into built distributions for as many platforms as there are packagers.

Of course, the module developer could be his own packager; or the packager could be a volunteer “out there” somewhere who has access to a platform which the original developer does not; or it could be software periodically grabbing new source distributions and turning them into built distributions for as many platforms as the software has access to. Regardless of who they are, a packager uses the setup script and the **bdist** command family to generate built distributions.

As a simple example, if I run the following command in the Distutils source tree:

```
python setup.py bdist
```

then the Distutils builds my module distribution (the Distutils itself in this case), does a “fake” installation (also in the `build` directory), and creates the default type of built distribution for my platform. The default format for built distributions is a “dumb” tar file on Unix, and a simple executable installer on Windows. (That tar file is considered “dumb” because it has to be unpacked in a specific location to work.)

Thus, the above command on a Unix system creates `Distutils-1.0.plat.tar.gz`; unpacking this tarball from the right place installs the Distutils just as though you had downloaded the source distribution and run `python setup.py install`. (The “right place” is either the root of the filesystem or Python’s `prefix` directory, depending on the options given to the **bdist\_dumb** command; the default is to make dumb distributions relative to `prefix`.)

Obviously, for pure Python distributions, this isn’t any simpler than just running `python setup.py install`—but for non-pure distributions, which include extensions that would need to be compiled, it can mean the difference between someone being able to use your extensions or not. And creating “smart” built distributions, such as an RPM package or an executable installer for Windows, is far more convenient for users even if your distribution doesn’t include any extensions.

The **bdist** command has a `--formats` option, similar to the **sdist** command, which you can use to select the types of built distribution to generate: for example,

```
python setup.py bdist --format=zip
```

would, when run on a Unix system, create `Distutils-1.0.plat.zip`—again, this archive would be unpacked from the root directory to install the Distutils.

The available formats for built distributions are:

| Format  | Description                          | Notes   |
|---------|--------------------------------------|---------|
| gztar   | gzipped tar file (.tar.gz)           | (1),(3) |
| ztar    | compressed tar file (.tar.Z)         | (3)     |
| tar     | tar file (.tar)                      | (3)     |
| zip     | zip file (.zip)                      | (2),(4) |
| rpm     | RPM                                  | (5)     |
| pkgtool | Solaris <b>pkgtool</b>               |         |
| sdux    | HP-UX <b>swinstall</b>               |         |
| wininst | self-extracting ZIP file for Windows | (4)     |
| msi     | Microsoft Installer.                 |         |

Notes:

1. default on Unix
2. default on Windows
3. requires external utilities: **tar** and possibly one of **gzip**, **bzip2**, or **compress**
4. requires either external **zip** utility or `zipfile` module (part of the standard Python library since Python 1.6)
5. requires external **rpm** utility, version 3.0.4 or better (use `rpm --version` to find out which version you have)

You don't have to use the **bdist** command with the `--formats` option; you can also use the command that directly implements the format you're interested in. Some of these **bdist** "sub-commands" actually generate several similar formats; for instance, the **bdist\_dumb** command generates all the "dumb" archive formats (`tar`, `ztar`, `gztar`, and `zip`), and **bdist\_rpm** generates both binary and source RPMs. The **bdist** sub-commands, and the formats generated by each, are:

| Command              | Formats               |
|----------------------|-----------------------|
| <b>bdist_dumb</b>    | tar, ztar, gztar, zip |
| <b>bdist_rpm</b>     | rpm, srpm             |
| <b>bdist_wininst</b> | wininst               |
| <b>bdist_msi</b>     | msi                   |

The following sections give details on the individual **bdist\_\*** commands.

## 5.1 Creating dumb built distributions

## 5.2 Creating RPM packages

The RPM format is used by many popular Linux distributions, including Red Hat, SuSE, and Mandrake. If one of these (or any of the other RPM-based Linux distributions) is your usual environment, creating RPM packages for other users of that same distribution is trivial. Depending on the complexity of your module distribution and differences between Linux distributions, you may also be able to create RPMs that work on different RPM-based distributions.

The usual way to create an RPM of your module distribution is to run the **bdist\_rpm** command:

```
python setup.py bdist_rpm
```

or the **bdist** command with the `--format` option:

```
python setup.py bdist --formats=rpm
```

The former allows you to specify RPM-specific options; the latter allows you to easily specify multiple formats in one run. If you need to do both, you can explicitly specify multiple **bdist\_\*** commands and their options:

```
python setup.py bdist_rpm --packager="John Doe <jdoe@example.org>" \
    bdist_wininst --target-version="2.0"
```

Creating RPM packages is driven by a `.spec` file, much as using the Distutils is driven by the setup script. To make your life easier, the `bdist_rpm` command normally creates a `.spec` file based on the information you supply in the setup script, on the command line, and in any Distutils configuration files. Various options and sections in the `.spec` file are derived from options in the setup script as follows:

| RPM <code>.spec</code> file option or section | Distutils setup script option                                                                                            |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Name                                          | <code>name</code>                                                                                                        |
| Summary (in preamble)                         | <code>description</code>                                                                                                 |
| Version                                       | <code>version</code>                                                                                                     |
| Vendor                                        | <code>author</code> and <code>author_email</code> , or <code>— &amp; maintainer</code> and <code>maintainer_email</code> |
| Copyright                                     | <code>license</code>                                                                                                     |
| Url                                           | <code>url</code>                                                                                                         |
| <code>%description</code> (section)           | <code>long_description</code>                                                                                            |

Additionally, there are many options in `.spec` files that don't have corresponding options in the setup script. Most of these are handled through options to the `bdist_rpm` command as follows:

| RPM <code>.spec</code> file option or section | <code>bdist_rpm</code> option  | default value           |
|-----------------------------------------------|--------------------------------|-------------------------|
| Release                                       | <code>release</code>           | "1"                     |
| Group                                         | <code>group</code>             | "Development/Libraries" |
| Vendor                                        | <code>vendor</code>            | (see above)             |
| Packager                                      | <code>packager</code>          | (none)                  |
| Provides                                      | <code>provides</code>          | (none)                  |
| Requires                                      | <code>requires</code>          | (none)                  |
| Conflicts                                     | <code>conflicts</code>         | (none)                  |
| Obsoletes                                     | <code>obsoletes</code>         | (none)                  |
| Distribution                                  | <code>distribution_name</code> | (none)                  |
| BuildRequires                                 | <code>build_requires</code>    | (none)                  |
| Icon                                          | <code>icon</code>              | (none)                  |

Obviously, supplying even a few of these options on the command-line would be tedious and error-prone, so it's usually best to put them in the setup configuration file, `setup.cfg`—see section [Writing the Setup Configuration File](#). If you distribute or package many Python module distributions, you might want to put options that apply to all of them in your personal Distutils configuration file (`~/.pydistutils.cfg`). If you want to temporarily disable this file, you can pass the `-no-user-cfg` option to `setup.py`.

There are three steps to building a binary RPM package, all of which are handled automatically by the Distutils:

1. create a `.spec` file, which describes the package (analogous to the Distutils setup script; in fact, much of the information in the setup script winds up in the `.spec` file)
2. create the source RPM
3. create the "binary" RPM (which may or may not contain binary code, depending on whether your module distribution contains Python extensions)

Normally, RPM bundles the last two steps together; when you use the Distutils, all three steps are typically bundled together.

If you wish, you can separate these three steps. You can use the `--spec-only` option to make `bdist_rpm` just create the `.spec` file and exit; in this case, the `.spec` file will be written to the "distribution directory"—normally `dist/`, but customizable with the `--dist-dir` option. (Normally, the `.spec` file winds up deep in the "build tree," in a temporary directory created by `bdist_rpm`.)

## 5.3 Creating Windows Installers

Executable installers are the natural format for binary distributions on Windows. They display a nice graphical user interface, display some information about the module distribution to be installed taken from the metadata in the setup script, let the user select a few options, and start or cancel the installation.

Since the metadata is taken from the setup script, creating Windows installers is usually as easy as running:

```
python setup.py bdist_wininst
```

or the **bdist** command with the `--formats` option:

```
python setup.py bdist --formats=wininst
```

If you have a pure module distribution (only containing pure Python modules and packages), the resulting installer will be version independent and have a name like `foo-1.0.win32.exe`. These installers can even be created on Unix platforms or Mac OS X.

If you have a non-pure distribution, the extensions can only be created on a Windows platform, and will be Python version dependent. The installer filename will reflect this and now has the form `foo-1.0.win32-py2.0.exe`. You have to create a separate installer for every Python version you want to support.

The installer will try to compile pure modules into *bytecode* after installation on the target system in normal and optimizing mode. If you don't want this to happen for some reason, you can run the **bdist\_wininst** command with the `--no-target-compile` and/or the `--no-target-optimize` option.

By default the installer will display the cool “Python Powered” logo when it is run, but you can also supply your own 152x261 bitmap which must be a Windows `.bmp` file with the `--bitmap` option.

The installer will also display a large title on the desktop background window when it is run, which is constructed from the name of your distribution and the version number. This can be changed to another text by using the `--title` option.

The installer file will be written to the “distribution directory” — normally `dist/`, but customizable with the `--dist-dir` option.

## 5.4 Cross-compiling on Windows

Starting with Python 2.6, distutils is capable of cross-compiling between Windows platforms. In practice, this means that with the correct tools installed, you can use a 32bit version of Windows to create 64bit extensions and vice-versa.

To build for an alternate platform, specify the `--plat-name` option to the build command. Valid values are currently ‘win32’, ‘win-amd64’ and ‘win-ia64’. For example, on a 32bit version of Windows, you could execute:

```
python setup.py build --plat-name=win-amd64
```

to build a 64bit version of your extension. The Windows Installers also support this option, so the command:

```
python setup.py build --plat-name=win-amd64 bdist_wininst
```

would create a 64bit installation executable on your 32bit version of Windows.

To cross-compile, you must download the Python source code and cross-compile Python itself for the platform you are targeting - it is not possible from a binary installation of Python (as the `.lib` etc file for other platforms are not included.) In practice, this means the user of a 32 bit operating system will need to use Visual Studio 2008 to open the `PCBuild/PCbuild.sln` solution in the Python source tree and build the “x64” configuration of the ‘pythoncore’ project before cross-compiling extensions is possible.

Note that by default, Visual Studio 2008 does not install 64bit compilers or tools. You may need to reexecute the Visual Studio setup process and select these tools (using Control Panel->[Add/Remove] Programs is a convenient way to check or modify your existing install.)

### 5.4.1 The Postinstallation script

Starting with Python 2.3, a postinstallation script can be specified with the `--install-script` option. The base-name of the script must be specified, and the script filename must also be listed in the scripts argument to the setup function.

This script will be run at installation time on the target system after all the files have been copied, with `argv[1]` set to `-install`, and again at uninstallation time before the files are removed with `argv[1]` set to `-remove`.

The installation script runs embedded in the windows installer, every output (`sys.stdout`, `sys.stderr`) is redirected into a buffer and will be displayed in the GUI after the script has finished.

Some functions especially useful in this context are available as additional built-in functions in the installation script.

**directory\_created** (*path*)

**file\_created** (*path*)

These functions should be called when a directory or file is created by the postinstall script at installation time. It will register *path* with the uninstaller, so that it will be removed when the distribution is uninstalled. To be safe, directories are only removed if they are empty.

**get\_special\_folder\_path** (*csidl\_string*)

This function can be used to retrieve special folder locations on Windows like the Start Menu or the Desktop. It returns the full path to the folder. *csidl\_string* must be one of the following strings:

"CSIDL\_APPDATA"

"CSIDL\_COMMON\_STARTMENU"

"CSIDL\_STARTMENU"

"CSIDL\_COMMON\_DESKTOPDIRECTORY"

"CSIDL\_DESKTOPDIRECTORY"

"CSIDL\_COMMON\_STARTUP"

"CSIDL\_STARTUP"

"CSIDL\_COMMON\_PROGRAMS"

"CSIDL\_PROGRAMS"

"CSIDL\_FONTS"

If the folder cannot be retrieved, `OSError` is raised.

Which folders are available depends on the exact Windows version, and probably also the configuration. For details refer to Microsoft's documentation of the `SHGetSpecialFolderPath()` function.

**create\_shortcut** (*target*, *description*, *filename* [, *arguments* [, *workdir* [, *iconpath* [, *iconindex* ] ] ] ])

This function creates a shortcut. *target* is the path to the program to be started by the shortcut. *description* is the description of the shortcut. *filename* is the title of the shortcut that the user will see. *arguments* specifies the command line arguments, if any. *workdir* is the working directory for the program. *iconpath* is the file containing the icon for the shortcut, and *iconindex* is the index of the icon in the file *iconpath*. Again, for details consult the Microsoft documentation for the `IShellLink` interface.

## 5.5 Vista User Access Control (UAC)

Starting with Python 2.6, `bdist_wininst` supports a `--user-access-control` option. The default is 'none' (meaning no UAC handling is done), and other valid values are 'auto' (meaning prompt for UAC elevation if Python was installed for all users) and 'force' (meaning always prompt for elevation).

# REGISTERING WITH THE PACKAGE INDEX

The Python Package Index (PyPI) holds meta-data describing distributions packaged with distutils. The distutils command **register** is used to submit your distribution's meta-data to the index. It is invoked as follows:

```
python setup.py register
```

Distutils will respond with the following prompt:

```
running register
```

```
We need to know who you are, so please choose either:
```

1. use your existing login,
2. register as a new user,
3. have the server generate a new password for you (and email it to you), or
4. quit

```
Your selection [default 1]:
```

Note: if your username and password are saved locally, you will not see this menu.

If you have not registered with PyPI, then you will need to do so now. You should choose option 2, and enter your details as required. Soon after submitting your details, you will receive an email which will be used to confirm your registration.

Once you are registered, you may choose option 1 from the menu. You will be prompted for your PyPI username and password, and **register** will then submit your meta-data to the index.

You may submit any number of versions of your distribution to the index. If you alter the meta-data for a particular version, you may submit it again and the index will be updated.

PyPI holds a record for each (name, version) combination submitted. The first user to submit information for a given name is designated the Owner of that name. They may submit changes through the **register** command or through the web interface. They may also designate other users as Owners or Maintainers. Maintainers may edit the package information, but not designate other Owners or Maintainers.

By default PyPI will list all versions of a given package. To hide certain versions, the Hidden property should be set to yes. This must be edited through the web interface.

## 6.1 The .pypirc file

The format of the `.pypirc` file is as follows:

```
[distutils]
index-servers =
```

```
pypi
```

```
[pypi]
repository: <repository-url>
username: <username>
password: <password>
```

The *distutils* section defines a *index-servers* variable that lists the name of all sections describing a repository.

Each section describing a repository defines three variables:

- **repository**, that defines the url of the PyPI server. Defaults to `http://www.python.org/pypi`.
- **username**, which is the registered username on the PyPI server.
- **password**, that will be used to authenticate. If omitted the user will be prompted to type it when needed.

If you want to define another server a new section can be created and listed in the *index-servers* variable:

```
[distutils]
index-servers =
    pypi
    other
```

```
[pypi]
repository: <repository-url>
username: <username>
password: <password>
```

```
[other]
repository: http://example.com/pypi
username: <username>
password: <password>
```

**register** can then be called with the `-r` option to point the repository to work with:

```
python setup.py register -r http://example.com/pypi
```

For convenience, the name of the section that describes the repository may also be used:

```
python setup.py register -r other
```

# UPLOADING PACKAGES TO THE PACKAGE INDEX

New in version 2.5. The Python Package Index (PyPI) not only stores the package info, but also the package data if the author of the package wishes to. The `distutils` command **upload** pushes the distribution files to PyPI.

The command is invoked immediately after building one or more distribution files. For example, the command

```
python setup.py sdist bdist_wininst upload
```

will cause the source distribution and the Windows installer to be uploaded to PyPI. Note that these will be uploaded even if they are built using an earlier invocation of `setup.py`, but that only distributions named on the command line for the invocation including the **upload** command are uploaded.

The **upload** command uses the username, password, and repository URL from the `$HOME/.pypirc` file (see section *The .pypirc file* for more on this file). If a **register** command was previously called in the same command, and if the password was entered in the prompt, **upload** will reuse the entered password. This is useful if you do not want to store a clear text password in the `$HOME/.pypirc` file.

You can specify another PyPI server with the `--repository=*url*` option:

```
python setup.py sdist bdist_wininst upload -r http://example.com/pypi
```

See section *The .pypirc file* for more on defining several servers.

You can use the `--sign` option to tell **upload** to sign each uploaded file using GPG (GNU Privacy Guard). The **gpg** program must be available for execution on the system `PATH`. You can also specify which key to use for signing using the `--identity=*name*` option.

Other **upload** options include `--repository=` or `--repository=` where *url* is the url of the server and *section* the name of the section in `$HOME/.pypirc`, and `--show-response` (which displays the full response text from the PyPI server for help in debugging upload problems).

## 7.1 PyPI package display

The `long_description` field plays a special role at PyPI. It is used by the server to display a home page for the registered package.

If you use the `reStructuredText` syntax for this field, PyPI will parse it and display an HTML output for the package home page.

The `long_description` field can be attached to a text file located in the package:

```
from distutils.core import setup
```

```
with open('README.txt') as file:
    long_description = file.read()

setup(name='Distutils',
      long_description=long_description)
```

In that case, `README.txt` is a regular `reStructuredText` text file located in the root of the package besides `setup.py`.

To prevent registering broken `reStructuredText` content, you can use the `rst2html` program that is provided by the `docutils` package and check the `long_description` from the command line:

```
$ python setup.py --long-description | rst2html.py > output.html
```

`docutils` will display a warning if there's something wrong with your syntax. Because PyPI applies additional checks (e.g. by passing `--no-raw` to `rst2html.py` in the command above), being able to run the command above without warnings does not guarantee that PyPI will convert the content successfully.

# EXAMPLES

This chapter provides a number of basic examples to help get started with distutils. Additional information about using distutils can be found in the Distutils Cookbook.

**See Also:**

**Distutils Cookbook** Collection of recipes showing how to achieve more control over distutils.

## 8.1 Pure Python distribution (by module)

If you're just distributing a couple of modules, especially if they don't live in a particular package, you can specify them individually using the `py_modules` option in the setup script.

In the simplest case, you'll have two files to worry about: a setup script and the single module you're distributing, `foo.py` in this example:

```
<root>/
    setup.py
    foo.py
```

(In all diagrams in this section, `<root>` will refer to the distribution root directory.) A minimal setup script to describe this situation would be:

```
from distutils.core import setup
setup(name='foo',
      version='1.0',
      py_modules=['foo'],
      )
```

Note that the name of the distribution is specified independently with the `name` option, and there's no rule that says it has to be the same as the name of the sole module in the distribution (although that's probably a good convention to follow). However, the distribution name is used to generate filenames, so you should stick to letters, digits, underscores, and hyphens.

Since `py_modules` is a list, you can of course specify multiple modules, eg. if you're distributing modules `foo` and `bar`, your setup might look like this:

```
<root>/
    setup.py
    foo.py
    bar.py
```

and the setup script might be

```
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      py_modules=['foo', 'bar'],
      )
```

You can put module source files into another directory, but if you have enough modules to do that, it's probably easier to specify modules by package rather than listing them individually.

## 8.2 Pure Python distribution (by package)

If you have more than a couple of modules to distribute, especially if they are in multiple packages, it's probably easier to specify whole packages rather than individual modules. This works even if your modules are not in a package; you can just tell the Distutils to process modules from the root package, and that works the same as any other package (except that you don't have to have an `__init__.py` file).

The setup script from the last example could also be written as

```
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      packages=[''],
      )
```

(The empty string stands for the root package.)

If those two files are moved into a subdirectory, but remain in the root package, e.g.:

```
<root>/
  setup.py
  src/   foo.py
        bar.py
```

then you would still specify the root package, but you have to tell the Distutils where source files in the root package live:

```
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      package_dir={'': 'src'},
      packages=[''],
      )
```

More typically, though, you will want to distribute multiple modules in the same package (or in sub-packages). For example, if the `foo` and `bar` modules belong in package `foobar`, one way to layout your source tree is

```
<root>/
  setup.py
  foobar/
    __init__.py
    foo.py
    bar.py
```

This is in fact the default layout expected by the Distutils, and the one that requires the least work to describe in your setup script:

```
from distutils.core import setup
setup(name='foobar',
```

```

    version='1.0',
    packages=['foobar'],
)

```

If you want to put modules in directories not named for their package, then you need to use the `package_dir` option again. For example, if the `src` directory holds modules in the `foobar` package:

```

<root>/
    setup.py
    src/
        __init__.py
        foo.py
        bar.py

```

an appropriate setup script would be

```

from distutils.core import setup
setup(name='foobar',
      version='1.0',
      package_dir={'foobar': 'src'},
      packages=['foobar'],
)

```

Or, you might put modules from your main package right in the distribution root:

```

<root>/
    setup.py
    __init__.py
    foo.py
    bar.py

```

in which case your setup script would be

```

from distutils.core import setup
setup(name='foobar',
      version='1.0',
      package_dir={'foobar': ''},
      packages=['foobar'],
)

```

(The empty string also stands for the current directory.)

If you have sub-packages, they must be explicitly listed in `packages`, but any entries in `package_dir` automatically extend to sub-packages. (In other words, the Distutils does *not* scan your source tree, trying to figure out which directories correspond to Python packages by looking for `__init__.py` files.) Thus, if the default layout grows a sub-package:

```

<root>/
    setup.py
    foobar/
        __init__.py
        foo.py
        bar.py
        subfoo/
            __init__.py
            blah.py

```

then the corresponding setup script would be

```
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      packages=['foobar', 'foobar.subfoo'],
      )
```

(Again, the empty string in *package\_dir* stands for the current directory.)

### 8.3 Single extension module

Extension modules are specified using the *ext\_modules* option. *package\_dir* has no effect on where extension source files are found; it only affects the source for pure Python modules. The simplest case, a single extension module in a single C source file, is:

```
<root>/
  setup.py
  foo.c
```

If the *foo* extension belongs in the root package, the setup script for this could be

```
from distutils.core import setup
from distutils.extension import Extension
setup(name='foobar',
      version='1.0',
      ext_modules=[Extension('foo', ['foo.c'])],
      )
```

If the extension actually belongs in a package, say *foopkg*, then

With exactly the same source tree layout, this extension can be put in the *foopkg* package simply by changing the name of the extension:

```
from distutils.core import setup
from distutils.extension import Extension
setup(name='foobar',
      version='1.0',
      ext_modules=[Extension('foopkg.foo', ['foo.c'])],
      )
```

# EXTENDING DISTUTILS

Distutils can be extended in various ways. Most extensions take the form of new commands or replacements for existing commands. New commands may be written to support new types of platform-specific packaging, for example, while replacements for existing commands may be made to modify details of how the command operates on a package.

Most extensions of the distutils are made within `setup.py` scripts that want to modify existing commands; many simply add a few file extensions that should be copied into packages in addition to `.py` files as a convenience.

Most distutils command implementations are subclasses of the `distutils.cmd.Command` class. New commands may directly inherit from `Command`, while replacements often derive from `Command` indirectly, directly subclassing the command they are replacing. Commands are required to derive from `Command`.

## 9.1 Integrating new commands

There are different ways to integrate new command implementations into distutils. The most difficult is to lobby for the inclusion of the new features in distutils itself, and wait for (and require) a version of Python that provides that support. This is really hard for many reasons.

The most common, and possibly the most reasonable for most needs, is to include the new implementations with your `setup.py` script, and cause the `distutils.core.setup()` function use them:

```
from distutils.command.build_py import build_py as _build_py
from distutils.core import setup

class build_py(_build_py):
    """Specialized Python source builder."""

    # implement whatever needs to be different...

setup(cmdclass={'build_py': build_py},
      ...)
```

This approach is most valuable if the new implementations must be used to use a particular package, as everyone interested in the package will need to have the new command implementation.

Beginning with Python 2.4, a third option is available, intended to allow new commands to be added which can support existing `setup.py` scripts without requiring modifications to the Python installation. This is expected to allow third-party extensions to provide support for additional packaging systems, but the commands can be used for anything distutils commands can be used for. A new configuration option, `command_packages` (command-line option `--command-packages`), can be used to specify additional packages to be searched for modules implementing commands. Like all distutils options, this can be specified on the command line or in a configuration file. This option can only be set in the `[global]` section of a configuration file, or before any commands on the command line. If set

in a configuration file, it can be overridden from the command line; setting it to an empty string on the command line causes the default to be used. This should never be set in a configuration file provided with a package.

This new option can be used to add any number of packages to the list of packages searched for command implementations; multiple package names should be separated by commas. When not specified, the search is only performed in the `distutils.command` package. When `setup.py` is run with the option `--command-packages distcmds, buildcmds`, however, the packages `distutils.command`, `distcmds`, and `buildcmds` will be searched in that order. New commands are expected to be implemented in modules of the same name as the command by classes sharing the same name. Given the example command line option above, the command `bdist_openpkg` could be implemented by the class `distcmds.bdist_openpkg.bdist_openpkg` or `buildcmds.bdist_openpkg.bdist_openpkg`.

## 9.2 Adding new distribution types

Commands that create distributions (files in the `dist/` directory) need to add `(command, filename)` pairs to `self.distribution.dist_files` so that **upload** can upload it to PyPI. The *filename* in the pair contains no path information, only the name of the file itself. In dry-run mode, pairs should still be added to represent what would have been created.

# COMMAND REFERENCE

## 10.1 Installing modules: the install command family

The install command ensures that the build commands have been run and then runs the subcommands **install\_lib**, **install\_data** and **install\_scripts**.

### 10.1.1 install\_data

This command installs all data files provided with the distribution.

### 10.1.2 install\_scripts

This command installs all (Python) scripts in the distribution.



# API REFERENCE

## 11.1 `distutils.core` — Core Distutils functionality

The `distutils.core` module is the only module that needs to be installed to use the Distutils. It provides the `setup()` (which is called from the setup script). Indirectly provides the `distutils.dist.Distribution` and `distutils.cmd.Command` class.

`distutils.core.setup` (*arguments*)

The basic do-everything function that does most everything you could ever ask for from a Distutils method.

The setup function takes a large number of arguments. These are laid out in the following table.

| argument name           | value                                                                     | type                                                                      |
|-------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| <i>name</i>             | The name of the package                                                   | a string                                                                  |
| <i>version</i>          | The version number of the package; see <code>distutils.version</code>     | a string                                                                  |
| <i>description</i>      | A single line describing the package                                      | a string                                                                  |
| <i>long_description</i> | Longer description of the package                                         | a string                                                                  |
| <i>author</i>           | The name of the package author                                            | a string                                                                  |
| <i>author_email</i>     | The email address of the package author                                   | a string                                                                  |
| <i>maintainer</i>       | The name of the current maintainer, if different from the author          | a string                                                                  |
| <i>maintainer_email</i> | The email address of the current maintainer, if different from the author | a string                                                                  |
| <i>url</i>              | A URL for the package (homepage)                                          | a string                                                                  |
| <i>download_url</i>     | A URL to download the package                                             | a string                                                                  |
| <i>packages</i>         | A list of Python packages that distutils will manipulate                  | a list of strings                                                         |
| <i>py_modules</i>       | A list of Python modules that distutils will manipulate                   | a list of strings                                                         |
| <i>scripts</i>          | A list of standalone script files to be built and installed               | a list of strings                                                         |
| <i>ext_modules</i>      | A list of Python extensions to be built                                   | a list of instances of <code>distutils.core.Extension</code>              |
| <i>classifiers</i>      | A list of categories for the package                                      | a list of strings; valid classifiers are listed on <a href="#">PyPI</a> . |
| <i>distclass</i>        | the <code>Distribution</code> class to use                                | a subclass of <code>distutils.core.Distribution</code>                    |
| <i>script_name</i>      | The name of the setup.py script - defaults to <code>sys.argv[0]</code>    | a string                                                                  |
| <i>script_args</i>      | Arguments to supply to the setup script                                   | a list of strings                                                         |
| <i>options</i>          | default options for the setup script                                      | a dictionary                                                              |
| <i>license</i>          | The license for the package                                               | a string                                                                  |
| <i>keywords</i>         | Descriptive meta-data, see <a href="#">PEP 314</a>                        | a list of strings or a comma-separated string                             |
| <i>platforms</i>        |                                                                           | a list of strings or a comma-separated string                             |
| <i>cmdclass</i>         | A mapping of command names to <code>Command</code> subclasses             | a dictionary                                                              |
| <i>data_files</i>       | A list of data files to install                                           | a list                                                                    |
| <i>package_dir</i>      | A mapping of package to directory names                                   | a dictionary                                                              |

`distutils.core.run_setup(script_name[, script_args=None, stop_after='run'])`

Run a setup script in a somewhat controlled environment, and return the `distutils.dist.Distribution` instance that drives things. This is useful if you need to find out the distribution meta-data (passed as keyword args from `script` to `setup()`), or the contents of the config files or command-line.

`script_name` is a file that will be run with `execfile()` `sys.argv[0]` will be replaced with `script` for the duration of the call. `script_args` is a list of strings; if supplied, `sys.argv[1:]` will be replaced by `script_args` for the duration of the call.

`stop_after` tells `setup()` when to stop processing; possible values:

| value               | description                                                                                                                                                             |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>init</i>         | Stop after the <code>Distribution</code> instance has been created and populated with the keyword arguments to <code>setup()</code>                                     |
| <i>config</i>       | Stop after config files have been parsed (and their data stored in the <code>Distribution</code> instance)                                                              |
| <i>command-line</i> | Stop after the command-line ( <code>sys.argv[1:]</code> or <code>script_args</code> ) have been parsed (and the data stored in the <code>Distribution</code> instance.) |
| <i>run</i>          | Stop after all commands have been run (the same as if <code>setup()</code> had been called in the usual way). This is the default value.                                |

In addition, the `distutils.core` module exposed a number of classes that live elsewhere.

- Extension from `distutils.extension`
- Command from `distutils.cmd`
- Distribution from `distutils.dist`

A short description of each of these follows, but see the relevant module for the full reference.

**class** `distutils.core.Extension`

The `Extension` class describes a single C or C++-extension module in a setup script. It accepts the following keyword arguments in its constructor

| argument name               | value                                                                                                                                                                                                                                                                                                                         | type              |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| <i>name</i>                 | the full name of the extension, including any packages — ie. <i>not</i> a filename or pathname, but Python dotted name                                                                                                                                                                                                        | a string          |
| <i>sources</i>              | list of source filenames, relative to the distribution root (where the setup script lives), in Unix form (slash-separated) for portability. Source files may be C, C++, SWIG (.i), platform-specific resource files, or whatever else is recognized by the <b>build_ext</b> command as source for a Python extension.         | a list of strings |
| <i>include_dirs</i>         | list of directories to search for C/C++ header files (in Unix form for portability)                                                                                                                                                                                                                                           | a list of strings |
| <i>define_macros</i>        | list of macros to define; each macro is defined using a 2-tuple ( <i>name</i> , <i>value</i> ), where <i>value</i> is either the string to define it to or <code>None</code> to define it without a particular value (equivalent of <code>#define FOO</code> in source or <code>-DFOO</code> on Unix C compiler command line) | a list of tuples  |
| <i>undef_macros</i>         | list of macros to undefine explicitly                                                                                                                                                                                                                                                                                         | a list of strings |
| <i>library_dirs</i>         | list of directories to search for C/C++ libraries at link time                                                                                                                                                                                                                                                                | a list of strings |
| <i>libraries</i>            | list of library names (not filenames or paths) to link against                                                                                                                                                                                                                                                                | a list of strings |
| <i>runtime_library_dirs</i> | list of directories to search for C/C++ libraries at run time (for shared extensions, this is when the extension is loaded)                                                                                                                                                                                                   | a list of strings |
| <i>extra_objects</i>        | list of extra files to link with (eg. object files not implied by 'sources', static library that must be explicitly specified, binary resource files, etc.)                                                                                                                                                                   | a list of strings |
| <i>extra_compile_args</i>   | any extra platform- and compiler-specific information to use when compiling the source files in 'sources'. For platforms and compilers where a command line makes sense, this is typically a list of command-line arguments, but for other platforms it could be anything.                                                    | a list of strings |
| <i>extra_link_args</i>      | any extra platform- and compiler-specific information to use when linking object files together to create the extension (or to create a new static Python interpreter). Similar interpretation as for 'extra_compile_args'.                                                                                                   | a list of strings |
| <i>export_symbols</i>       | list of symbols to be exported from a shared extension. Not used on all platforms, and not generally necessary for Python extensions, which typically export exactly one symbol: <code>init + extension_name</code> .                                                                                                         | a list of strings |
| <i>depends</i>              | list of files that the extension depends on                                                                                                                                                                                                                                                                                   | a list of strings |
| <i>language</i>             | extension language (i.e. 'c', 'c++', 'objc'). Will be detected from the source extensions if not provided.                                                                                                                                                                                                                    | a string          |

**class** `distutils.core.Distribution`

A `Distribution` describes how to build, install and package up a Python software package.

See the `setup()` function for a list of keyword arguments accepted by the `Distribution` constructor. `setup()` creates a `Distribution` instance.

**class** `distutils.core.Command`

A `Command` class (or rather, an instance of one of its subclasses) implement a single `distutils` command.

## 11.2 `distutils.ccompiler` — CCompiler base class

This module provides the abstract base class for the `CCompiler` classes. A `CCompiler` instance can be used for all the compile and link steps needed to build a single project. Methods are provided to set options for the compiler — macro definitions, include directories, link path, libraries and the like.

This module provides the following functions.

`distutils.ccompiler.gen_lib_options` (*compiler, library\_dirs, runtime\_library\_dirs, libraries*)

Generate linker options for searching library directories and linking with specific libraries. *libraries* and *library\_dirs* are, respectively, lists of library names (not filenames!) and search directories. Returns a list of command-line options suitable for use with some compiler (depending on the two format strings passed in).

`distutils.ccompiler.gen_preprocess_options` (*macros, include\_dirs*)

Generate C pre-processor options (*-D*, *-U*, *-I*) as used by at least two types of compilers: the typical Unix compiler and Visual C++. *macros* is the usual thing, a list of 1- or 2-tuples, where *(name, )* means undefine (*-U*) macro *name*, and *(name, value)* means define (*-D*) macro *name* to *value*. *include\_dirs* is just a list of directory names to be added to the header file search path (*-I*). Returns a list of command-line options suitable for either Unix compilers or Visual C++.

`distutils.ccompiler.get_default_compiler` (*osname, platform*)

Determine the default compiler to use for the given platform.

*osname* should be one of the standard Python OS names (i.e. the ones returned by `os.name`) and *platform* the common value returned by `sys.platform` for the platform in question.

The default values are `os.name` and `sys.platform` in case the parameters are not given.

`distutils.ccompiler.new_compiler` (*plat=None, compiler=None, verbose=0, dry\_run=0, force=0*)

Factory function to generate an instance of some `CCompiler` subclass for the supplied platform/compiler combination. *plat* defaults to `os.name` (eg. `'posix'`, `'nt'`), and *compiler* defaults to the default compiler for that platform. Currently only `'posix'` and `'nt'` are supported, and the default compilers are “traditional Unix interface” (`UnixCCompiler` class) and Visual C++ (`MSVCCompiler` class). Note that it’s perfectly possible to ask for a Unix compiler object under Windows, and a Microsoft compiler object under Unix—if you supply a value for *compiler*, *plat* is ignored.

`distutils.ccompiler.show_compilers` ()

Print list of available compilers (used by the `--help-compiler` options to `build`, `build_ext`, `build_clib`).

**class** `distutils.ccompiler.CCompiler` (*[verbose=0, dry\_run=0, force=0]*)

The abstract base class `CCompiler` defines the interface that must be implemented by real compiler classes. The class also has some utility methods used by several compiler classes.

The basic idea behind a compiler abstraction class is that each instance can be used for all the compile/link steps in building a single project. Thus, attributes common to all of those compile and link steps — include directories, macros to define, libraries to link against, etc. — are attributes of the compiler instance. To allow for variability in how individual files are treated, most of those attributes may be varied on a per-compilation or per-link basis.

The constructor for each subclass creates an instance of the Compiler object. Flags are *verbose* (show verbose output), *dry\_run* (don’t actually execute the steps) and *force* (rebuild everything, regardless of dependencies). All of these flags default to 0 (off). Note that you probably don’t want to instantiate `CCompiler` or one of its subclasses directly - use the `distutils.CCompiler.new_compiler()` factory function instead.

The following methods allow you to manually alter compiler options for the instance of the Compiler class.

`add_include_dir` (*dir*)

Add *dir* to the list of directories that will be searched for header files. The compiler is instructed to search directories in the order in which they are supplied by successive calls to `add_include_dir()`.

### **set\_include\_dirs** (*dirs*)

Set the list of directories that will be searched to *dirs* (a list of strings). Overrides any preceding calls to `add_include_dir()`; subsequent calls to `add_include_dir()` add to the list passed to `set_include_dirs()`. This does not affect any list of standard include directories that the compiler may search by default.

### **add\_library** (*libname*)

Add *libname* to the list of libraries that will be included in all links driven by this compiler object. Note that *libname* should \*not\* be the name of a file containing a library, but the name of the library itself: the actual filename will be inferred by the linker, the compiler, or the compiler class (depending on the platform).

The linker will be instructed to link against libraries in the order they were supplied to `add_library()` and/or `set_libraries()`. It is perfectly valid to duplicate library names; the linker will be instructed to link against libraries as many times as they are mentioned.

### **set\_libraries** (*libnames*)

Set the list of libraries to be included in all links driven by this compiler object to *libnames* (a list of strings). This does not affect any standard system libraries that the linker may include by default.

### **add\_library\_dir** (*dir*)

Add *dir* to the list of directories that will be searched for libraries specified to `add_library()` and `set_libraries()`. The linker will be instructed to search for libraries in the order they are supplied to `add_library_dir()` and/or `set_library_dirs()`.

### **set\_library\_dirs** (*dirs*)

Set the list of library search directories to *dirs* (a list of strings). This does not affect any standard library search path that the linker may search by default.

### **add\_runtime\_library\_dir** (*dir*)

Add *dir* to the list of directories that will be searched for shared libraries at runtime.

### **set\_runtime\_library\_dirs** (*dirs*)

Set the list of directories to search for shared libraries at runtime to *dirs* (a list of strings). This does not affect any standard search path that the runtime linker may search by default.

### **define\_macro** (*name* [, *value=None* ])

Define a preprocessor macro for all compilations driven by this compiler object. The optional parameter *value* should be a string; if it is not supplied, then the macro will be defined without an explicit value and the exact outcome depends on the compiler used.

### **undefine\_macro** (*name*)

Undefine a preprocessor macro for all compilations driven by this compiler object. If the same macro is defined by `define_macro()` and undefined by `undefine_macro()` the last call takes precedence (including multiple redefinitions or undefinitions). If the macro is redefined/undefined on a per-compilation basis (ie. in the call to `compile()`), then that takes precedence.

### **add\_link\_object** (*object*)

Add *object* to the list of object files (or analogues, such as explicitly named library files or the output of “resource compilers”) to be included in every link driven by this compiler object.

### **set\_link\_objects** (*objects*)

Set the list of object files (or analogues) to be included in every link to *objects*. This does not affect any standard object files that the linker may include by default (such as system libraries).

The following methods implement methods for autodetection of compiler options, providing some functionality similar to GNU **autoconf**.

### **detect\_language** (*sources*)

Detect the language of a given file, or list of files. Uses the instance attributes `language_map` (a dictionary), and `language_order` (a list) to do the job.

**find\_library\_file** (*dirs*, *lib* [, *debug=0* ])

Search the specified list of directories for a static or shared library file *lib* and return the full path to that file. If *debug* is true, look for a debugging version (if that makes sense on the current platform). Return `None` if *lib* wasn't found in any of the specified directories.

**has\_function** (*funcname* [, *includes=None*, *include\_dirs=None*, *libraries=None*, *library\_dirs=None* ])

Return a boolean indicating whether *funcname* is supported on the current platform. The optional arguments can be used to augment the compilation environment by providing additional include files and paths and libraries and paths.

**library\_dir\_option** (*dir*)

Return the compiler option to add *dir* to the list of directories searched for libraries.

**library\_option** (*lib*)

Return the compiler option to add *lib* to the list of libraries linked into the shared library or executable.

**runtime\_library\_dir\_option** (*dir*)

Return the compiler option to add *dir* to the list of directories searched for runtime libraries.

**set\_executables** (\*\**args*)

Define the executables (and options for them) that will be run to perform the various stages of compilation. The exact set of executables that may be specified here depends on the compiler class (via the 'executables' class attribute), but most will have:

| attribute         | description                                        |
|-------------------|----------------------------------------------------|
| <i>compiler</i>   | the C/C++ compiler                                 |
| <i>linker_so</i>  | linker used to create shared objects and libraries |
| <i>linker_exe</i> | linker used to create binary executables           |
| <i>archiver</i>   | static library creator                             |

On platforms with a command-line (Unix, DOS/Windows), each of these is a string that will be split into executable name and (optional) list of arguments. (Splitting the string is done similarly to how Unix shells operate: words are delimited by spaces, but quotes and backslashes can override this. See `distutils.util.split_quoted()`.)

The following methods invoke stages in the build process.

**compile** (*sources* [, *output\_dir=None*, *macros=None*, *include\_dirs=None*, *debug=0*, *extra\_preargs=None*, *extra\_postargs=None*, *depends=None* ])

Compile one or more source files. Generates object files (e.g. transforms a `.c` file to a `.o` file.)

*sources* must be a list of filenames, most likely C/C++ files, but in reality anything that can be handled by a particular compiler and compiler class (eg. `MSVCCompiler` can handle resource files in *sources*). Return a list of object filenames, one per source filename in *sources*. Depending on the implementation, not all source files will necessarily be compiled, but all corresponding object filenames will be returned.

If *output\_dir* is given, object files will be put under it, while retaining their original path component. That is, `foo/bar.c` normally compiles to `foo/bar.o` (for a Unix implementation); if *output\_dir* is `build`, then it would compile to `build/foo/bar.o`.

*macros*, if given, must be a list of macro definitions. A macro definition is either a `(name, value)` 2-tuple or a `(name,)` 1-tuple. The former defines a macro; if the value is `None`, the macro is defined without an explicit value. The 1-tuple case undefines a macro. Later definitions/redefinitions/undefinitions take precedence.

*include\_dirs*, if given, must be a list of strings, the directories to add to the default include file search path for this compilation only.

*debug* is a boolean; if true, the compiler will be instructed to output debug symbols in (or alongside) the object file(s).

*extra\_preargs* and *extra\_postargs* are implementation-dependent. On platforms that have the notion of a command-line (e.g. Unix, DOS/Windows), they are most likely lists of strings: extra command-line arguments to prepend/append to the compiler command line. On other platforms, consult the implementation class documentation. In any event, they are intended as an escape hatch for those occasions when the abstract compiler framework doesn't cut the mustard.

*depends*, if given, is a list of filenames that all targets depend on. If a source file is older than any file in *depends*, then the source file will be recompiled. This supports dependency tracking, but only at a coarse granularity.

Raises `CompileError` on failure.

**create\_static\_lib** (*objects*, *output\_libname*[, *output\_dir*=None, *debug*=0, *target\_lang*=None ])

Link a bunch of stuff together to create a static library file. The “bunch of stuff” consists of the list of object files supplied as *objects*, the extra object files supplied to `add_link_object()` and/or `set_link_objects()`, the libraries supplied to `add_library()` and/or `set_libraries()`, and the libraries supplied as *libraries* (if any).

*output\_libname* should be a library name, not a filename; the filename will be inferred from the library name. *output\_dir* is the directory where the library file will be put.

*debug* is a boolean; if true, debugging information will be included in the library (note that on most platforms, it is the compile step where this matters: the *debug* flag is included here just for consistency).

*target\_lang* is the target language for which the given objects are being compiled. This allows specific linkage time treatment of certain languages.

Raises `LibError` on failure.

**link** (*target\_desc*, *objects*, *output\_filename*[, *output\_dir*=None, *libraries*=None, *library\_dirs*=None, *runtime\_library\_dirs*=None, *export\_symbols*=None, *debug*=0, *extra\_preargs*=None, *extra\_postargs*=None, *build\_temp*=None, *target\_lang*=None ])

Link a bunch of stuff together to create an executable or shared library file.

The “bunch of stuff” consists of the list of object files supplied as *objects*. *output\_filename* should be a filename. If *output\_dir* is supplied, *output\_filename* is relative to it (i.e. *output\_filename* can provide directory components if needed).

*libraries* is a list of libraries to link against. These are library names, not filenames, since they're translated into filenames in a platform-specific way (eg. *foo* becomes `libfoo.a` on Unix and `foo.lib` on DOS/Windows). However, they can include a directory component, which means the linker will look in that specific directory rather than searching all the normal locations.

*library\_dirs*, if supplied, should be a list of directories to search for libraries that were specified as bare library names (ie. no directory component). These are on top of the system default and those supplied to `add_library_dir()` and/or `set_library_dirs()`. *runtime\_library\_dirs* is a list of directories that will be embedded into the shared library and used to search for other shared libraries that *\*it\** depends on at run-time. (This may only be relevant on Unix.)

*export\_symbols* is a list of symbols that the shared library will export. (This appears to be relevant only on Windows.)

*debug* is as for `compile()` and `create_static_lib()`, with the slight distinction that it actually matters on most platforms (as opposed to `create_static_lib()`, which includes a *debug* flag mostly for form's sake).

*extra\_preargs* and *extra\_postargs* are as for `compile()` (except of course that they supply command-line arguments for the particular linker being used).

*target\_lang* is the target language for which the given objects are being compiled. This allows specific linkage time treatment of certain languages.

Raises `LinkError` on failure.

**link\_executable** (*objects*, *output\_progname* [, *output\_dir=None*, *libraries=None*, *library\_dirs=None*, *runtime\_library\_dirs=None*, *debug=0*, *extra\_preargs=None*, *extra\_postargs=None*, *target\_lang=None* ])

Link an executable. *output\_progname* is the name of the file executable, while *objects* are a list of object filenames to link in. Other arguments are as for the `link()` method.

**link\_shared\_lib** (*objects*, *output\_libname* [, *output\_dir=None*, *libraries=None*, *library\_dirs=None*, *runtime\_library\_dirs=None*, *export\_symbols=None*, *debug=0*, *extra\_preargs=None*, *extra\_postargs=None*, *build\_temp=None*, *target\_lang=None* ])

Link a shared library. *output\_libname* is the name of the output library, while *objects* is a list of object filenames to link in. Other arguments are as for the `link()` method.

**link\_shared\_object** (*objects*, *output\_filename* [, *output\_dir=None*, *libraries=None*, *library\_dirs=None*, *runtime\_library\_dirs=None*, *export\_symbols=None*, *debug=0*, *extra\_preargs=None*, *extra\_postargs=None*, *build\_temp=None*, *target\_lang=None* ])

Link a shared object. *output\_filename* is the name of the shared object that will be created, while *objects* is a list of object filenames to link in. Other arguments are as for the `link()` method.

**preprocess** (*source* [, *output\_file=None*, *macros=None*, *include\_dirs=None*, *extra\_preargs=None*, *extra\_postargs=None* ])

Preprocess a single C/C++ source file, named in *source*. Output will be written to file named *output\_file*, or *stdout* if *output\_file* not supplied. *macros* is a list of macro definitions as for `compile()`, which will augment the macros set with `define_macro()` and `undefine_macro()`. *include\_dirs* is a list of directory names that will be added to the default list, in the same way as `add_include_dir()`.

Raises `PreprocessError` on failure.

The following utility methods are defined by the `CCompiler` class, for use by the various concrete subclasses.

**executable\_filename** (*basename* [, *strip\_dir=0*, *output\_dir=''* ])

Returns the filename of the executable for the given *basename*. Typically for non-Windows platforms this is the same as the *basename*, while Windows will get a `.exe` added.

**library\_filename** (*libname* [, *lib\_type='static'*, *strip\_dir=0*, *output\_dir=''* ])

Returns the filename for the given library name on the current platform. On Unix a library with *lib\_type* of `'static'` will typically be of the form `liblibname.a`, while a *lib\_type* of `'dynamic'` will be of the form `liblibname.so`.

**object\_filenames** (*source\_filenames* [, *strip\_dir=0*, *output\_dir=''* ])

Returns the name of the object files for the given source files. *source\_filenames* should be a list of filenames.

**shared\_object\_filename** (*basename* [, *strip\_dir=0*, *output\_dir=''* ])

Returns the name of a shared object file for the given file name *basename*.

**execute** (*func*, *args* [, *msg=None*, *level=1* ])

Invokes `distutils.util.execute()`. This method invokes a Python function *func* with the given arguments *args*, after logging and taking into account the *dry\_run* flag.

**spawn** (*cmd*)

Invokes `distutils.util.spawn()`. This invokes an external process to run the given command.

**mkpath** (*name* [, *mode=511* ])

Invokes `distutils.dir_util.mkpath()`. This creates a directory and any missing ancestor directories.

**move\_file** (*src*, *dst*)

Invokes `distutils.file_util.move_file()`. Renames *src* to *dst*.

**announce** (*msg* [, *level=1* ])

Write a message using `distutils.log.debug()`.

**warn** (*msg*)

Write a warning message *msg* to standard error.

**debug\_print** (*msg*)

If the *debug* flag is set on this `CCompiler` instance, print *msg* to standard output, otherwise do nothing.

### 11.3 `distutils.unixccompiler` — Unix C Compiler

This module provides the `UnixCCompiler` class, a subclass of `CCompiler` that handles the typical Unix-style command-line C compiler:

- macros defined with `-Dname [=value]`
- macros undefined with `-Uname`
- include search directories specified with `-Idir`
- libraries specified with `-llib`
- library search directories specified with `-Ldir`
- compile handled by `cc` (or similar) executable with `-c` option: compiles `.c` to `.o`
- link static library handled by `ar` command (possibly with `ranlib`)
- link shared library handled by `cc -shared`

### 11.4 `distutils.msvccompiler` — Microsoft Compiler

This module provides `MSVCCompiler`, an implementation of the abstract `CCompiler` class for Microsoft Visual Studio. Typically, extension modules need to be compiled with the same compiler that was used to compile Python. For Python 2.3 and earlier, the compiler was Visual Studio 6. For Python 2.4 and 2.5, the compiler is Visual Studio .NET 2003. The AMD64 and Itanium binaries are created using the Platform SDK.

`MSVCCompiler` will normally choose the right compiler, linker etc. on its own. To override this choice, the environment variables `DISTUTILS_USE_SDK` and `MSSdk` must be both set. `MSSdk` indicates that the current environment has been setup by the SDK's `SetEnv.Cmd` script, or that the environment variables had been registered when the SDK was installed; `DISTUTILS_USE_SDK` indicates that the `distutils` user has made an explicit choice to override the compiler selection by `MSVCCompiler`.

### 11.5 `distutils.bccppcompiler` — Borland Compiler

This module provides `BorlandCCompiler`, an subclass of the abstract `CCompiler` class for the Borland C++ compiler.

## 11.6 `distutils.cygwincompiler` — Cygwin Compiler

This module provides the `CygwinCCompiler` class, a subclass of `UnixCCompiler` that handles the Cygwin port of the GNU C compiler to Windows. It also contains the `Mingw32CCompiler` class which handles the mingw32 port of GCC (same as cygwin in no-cygwin mode).

## 11.7 `distutils.emxccompiler` — OS/2 EMX Compiler

This module provides the `EMXCCompiler` class, a subclass of `UnixCCompiler` that handles the EMX port of the GNU C compiler to OS/2.

## 11.8 `distutils.archive_util` — Archiving utilities

This module provides a few functions for creating archive files, such as tarballs or zipfiles.

`distutils.archive_util.make_archive` (*base\_name*, *format* [, *root\_dir=None*, *base\_dir=None*, *verbose=0*, *dry\_run=0*])

Create an archive file (eg. zip or tar). *base\_name* is the name of the file to create, minus any format-specific extension; *format* is the archive format: one of zip, tar, ztar, or gztar. *root\_dir* is a directory that will be the root directory of the archive; ie. we typically `chdir` into *root\_dir* before creating the archive. *base\_dir* is the directory where we start archiving from; ie. *base\_dir* will be the common prefix of all files and directories in the archive. *root\_dir* and *base\_dir* both default to the current directory. Returns the name of the archive file.

`distutils.archive_util.make_tarball` (*base\_name*, *base\_dir* [, *compress='gzip'*, *verbose=0*, *dry\_run=0*])

‘Create an (optional compressed) archive as a tar file from all files in and under *base\_dir*. *compress* must be ‘gzip’ (the default), ‘compress’, ‘bzip2’, or None. Both **tar** and the compression utility named by *compress* must be on the default program search path, so this is probably Unix-specific. The output tar file will be named *base\_dir.tar*, possibly plus the appropriate compression extension (.gz, .bz2 or .Z). Return the output filename.

`distutils.archive_util.make_zipfile` (*base\_name*, *base\_dir* [, *verbose=0*, *dry\_run=0*])

Create a zip file from all files in and under *base\_dir*. The output zip file will be named *base\_name* + .zip. Uses either the `zipfile` Python module (if available) or the `InfoZIP zip` utility (if installed and found on the default search path). If neither tool is available, raises `DistutilsExecError`. Returns the name of the output zip file.

## 11.9 `distutils.dep_util` — Dependency checking

This module provides functions for performing simple, timestamp-based dependency of files and groups of files; also, functions based entirely on such timestamp dependency analysis.

`distutils.dep_util.newer` (*source*, *target*)

Return true if *source* exists and is more recently modified than *target*, or if *source* exists and *target* doesn’t. Return false if both exist and *target* is the same age or newer than *source*. Raise `DistutilsFileError` if *source* does not exist.

`distutils.dep_util.newer_pairwise` (*sources*, *targets*)

Walk two filename lists in parallel, testing if each source is newer than its corresponding target. Return a pair of lists (*sources*, *targets*) where source is newer than target, according to the semantics of `newer()`

`distutils.dep_util.newer_group(sources, target[, missing='error'])`

Return true if *target* is out-of-date with respect to any file listed in *sources*. In other words, if *target* exists and is newer than every file in *sources*, return false; otherwise return true. *missing* controls what we do when a source file is missing; the default ('error') is to blow up with an `OSError` from inside `os.stat()`; if it is 'ignore', we silently drop any missing source files; if it is 'newer', any missing source files make us assume that *target* is out-of-date (this is handy in “dry-run” mode: it’ll make you pretend to carry out commands that wouldn’t work because inputs are missing, but that doesn’t matter because you’re not actually going to run the commands).

## 11.10 `distutils.dir_util` — Directory tree operations

This module provides functions for operating on directories and trees of directories.

`distutils.dir_util.mkpath(name[, mode=0777, verbose=0, dry_run=0])`

Create a directory and any missing ancestor directories. If the directory already exists (or if *name* is the empty string, which means the current directory, which of course exists), then do nothing. Raise `DistutilsFileError` if unable to create some directory along the way (eg. some sub-path exists, but is a file rather than a directory). If *verbose* is true, print a one-line summary of each `mkdir` to `stdout`. Return the list of directories actually created.

`distutils.dir_util.create_tree(base_dir, files[, mode=0777, verbose=0, dry_run=0])`

Create all the empty directories under *base\_dir* needed to put *files* there. *base\_dir* is just the a name of a directory which doesn’t necessarily exist yet; *files* is a list of filenames to be interpreted relative to *base\_dir*. *base\_dir* + the directory portion of every file in *files* will be created if it doesn’t already exist. *mode*, *verbose* and *dry\_run* flags are as for `mkpath()`.

`distutils.dir_util.copy_tree(src, dst[, preserve_mode=1, preserve_times=1, preserve_symlinks=0, update=0, verbose=0, dry_run=0])`

Copy an entire directory tree *src* to a new location *dst*. Both *src* and *dst* must be directory names. If *src* is not a directory, raise `DistutilsFileError`. If *dst* does not exist, it is created with `mkpath()`. The end result of the copy is that every file in *src* is copied to *dst*, and directories under *src* are recursively copied to *dst*. Return the list of files that were copied or might have been copied, using their output name. The return value is unaffected by *update* or *dry\_run*: it is simply the list of all files under *src*, with the names changed to be under *dst*.

*preserve\_mode* and *preserve\_times* are the same as for `copy_file()` in `distutils.file_util`; note that they only apply to regular files, not to directories. If *preserve\_symlinks* is true, symlinks will be copied as symlinks (on platforms that support them!); otherwise (the default), the destination of the symlink will be copied. *update* and *verbose* are the same as for `copy_file()`.

Files in *src* that begin with `.nfs` are skipped (more information on these files is available in answer D2 of the [NFS FAQ page](#)).

`distutils.dir_util.remove_tree(directory[, verbose=0, dry_run=0])`

Recursively remove *directory* and all files and directories underneath it. Any errors are ignored (apart from being reported to `sys.stdout` if *verbose* is true).

## 11.11 `distutils.file_util` — Single file operations

This module contains some utility functions for operating on individual files.

`distutils.file_util.copy_file(src, dst[, preserve_mode=1, preserve_times=1, update=0, link=None, verbose=0, dry_run=0])`

Copy file *src* to *dst*. If *dst* is a directory, then *src* is copied there with the same name; otherwise, it must be

a filename. (If the file exists, it will be ruthlessly clobbered.) If *preserve\_mode* is true (the default), the file's mode (type and permission bits, or whatever is analogous on the current platform) is copied. If *preserve\_times* is true (the default), the last-modified and last-access times are copied as well. If *update* is true, *src* will only be copied if *dst* does not exist, or if *dst* does exist but is older than *src*.

*link* allows you to make hard links (using `os.link()`) or symbolic links (using `os.symlink()`) instead of copying: set it to 'hard' or 'sym'; if it is None (the default), files are copied. Don't set *link* on systems that don't support it: `copy_file()` doesn't check if hard or symbolic linking is available. It uses `_copy_file_contents()` to copy file contents.

Return a tuple (*dest\_name*, *copied*): *dest\_name* is the actual name of the output file, and *copied* is true if the file was copied (or would have been copied, if *dry\_run* true).

`distutils.file_util.move_file(src, dst[, verbose, dry_run])`

Move file *src* to *dst*. If *dst* is a directory, the file will be moved into it with the same name; otherwise, *src* is just renamed to *dst*. Returns the new full name of the file.

**Warning:** Handles cross-device moves on Unix using `copy_file()`. What about other systems?

`distutils.file_util.write_file(filename, contents)`

Create a file called *filename* and write *contents* (a sequence of strings without line terminators) to it.

## 11.12 distutils.util — Miscellaneous other utility functions

This module contains other assorted bits and pieces that don't fit into any other utility module.

`distutils.util.get_platform()`

Return a string that identifies the current platform. This is used mainly to distinguish platform-specific build directories and platform-specific built distributions. Typically includes the OS name and version and the architecture (as supplied by 'os.uname()'), although the exact information included depends on the OS; eg. for IRIX the architecture isn't particularly important (IRIX only runs on SGI hardware), but for Linux the kernel version isn't particularly important.

Examples of returned values:

- linux-i586
- linux-alpha
- solaris-2.6-sun4u
- irix-5.3
- irix64-6.2

For non-POSIX platforms, currently just returns `sys.platform`.

For Mac OS X systems the OS version reflects the minimal version on which binaries will run (that is, the value of `MACOSX_DEPLOYMENT_TARGET` during the build of Python), not the OS version of the current system.

For universal binary builds on Mac OS X the architecture value reflects the universal binary status instead of the architecture of the current processor. For 32-bit universal binaries the architecture is `fat`, for 64-bit universal binaries the architecture is `fat64`, and for 4-way universal binaries the architecture is `universal`. Starting from Python 2.7 and Python 3.2 the architecture `fat3` is used for a 3-way universal build (`ppc`, `i386`, `x86_64`) and `intel` is used for a universal build with the `i386` and `x86_64` architectures

Examples of returned values on Mac OS X:

- macosx-10.3-ppc

- `macosx-10.3-fat`
- `macosx-10.5-universal`
- `macosx-10.6-intel`

`distutils.util.convert_path(pathname)`

Return `pathname` as a name that will work on the native filesystem, i.e. split it on `'/'` and put it back together again using the current directory separator. Needed because filenames in the setup script are always supplied in Unix style, and have to be converted to the local convention before we can actually use them in the filesystem. Raises `ValueError` on non-Unix-ish systems if `pathname` either starts or ends with a slash.

`distutils.util.change_root(new_root, pathname)`

Return `pathname` with `new_root` prepended. If `pathname` is relative, this is equivalent to `os.path.join(new_root, pathname)`. Otherwise, it requires making `pathname` relative and then joining the two, which is tricky on DOS/Windows.

`distutils.util.check_envIRON()`

Ensure that `os.environ` has all the environment variables we guarantee that users can use in config files, command-line options, etc. Currently this includes:

- `HOME` - user's home directory (Unix only)
- `PLAT` - description of the current platform, including hardware and OS (see `get_platform()`)

`distutils.util.subst_vars(s, local_vars)`

Perform shell/Perl-style variable substitution on `s`. Every occurrence of `$` followed by a name is considered a variable, and variable is substituted by the value found in the `local_vars` dictionary, or in `os.environ` if it's not in `local_vars`. `os.environ` is first checked/augmented to guarantee that it contains certain values: see `check_envIRON()`. Raise `ValueError` for any variables not found in either `local_vars` or `os.environ`.

Note that this is not a fully-fledged string interpolation function. A valid `$variable` can consist only of upper and lower case letters, numbers and an underscore. No `{ }` or `( )` style quoting is available.

`distutils.util.grok_environment_error(exc[, prefix='error: '])`

Generate a useful error message from an `EnvironmentError` (`IOError` or `OSError`) exception object. Handles Python 1.5.1 and later styles, and does what it can to deal with exception objects that don't have a filename (which happens when the error is due to a two-file operation, such as `rename()` or `link()`). Returns the error message as a string prefixed with `prefix`.

`distutils.util.split_quoted(s)`

Split a string up according to Unix shell-like rules for quotes and backslashes. In short: words are delimited by spaces, as long as those spaces are not escaped by a backslash, or inside a quoted string. Single and double quotes are equivalent, and the quote characters can be backslash-escaped. The backslash is stripped from any two-character escape sequence, leaving only the escaped character. The quote characters are stripped from any quoted string. Returns a list of words.

`distutils.util.execute(func, args[, msg=None, verbose=0, dry_run=0])`

Perform some action that affects the outside world (for instance, writing to the filesystem). Such actions are special because they are disabled by the `dry_run` flag. This method takes care of all that bureaucracy for you; all you have to do is supply the function to call and an argument tuple for it (to embody the "external action" being performed), and an optional message to print.

`distutils.util.strtobool(val)`

Convert a string representation of truth to true (1) or false (0).

True values are `y`, `yes`, `t`, `true`, `on` and `1`; false values are `n`, `no`, `f`, `false`, `off` and `0`. Raises `ValueError` if `val` is anything else.

`distutils.util.byte_compile(py_files[, optimize=0, force=0, prefix=None, base_dir=None, verbose=1, dry_run=0, direct=None])`

Byte-compile a collection of Python source files to either `.pyc` or `.pyo` files in the same directory. `py_files`

is a list of files to compile; any files that don't end in `.py` are silently skipped. *optimize* must be one of the following:

- 0 - don't optimize (generate `.pyc`)
- 1 - normal optimization (like `python -O`)
- 2 - extra optimization (like `python -OO`)

If *force* is true, all files are recompiled regardless of timestamps.

The source filename encoded in each *bytecode* file defaults to the filenames listed in *py\_files*; you can modify these with *prefix* and *basedir*. *prefix* is a string that will be stripped off of each source filename, and *base\_dir* is a directory name that will be prepended (after *prefix* is stripped). You can supply either or both (or neither) of *prefix* and *base\_dir*, as you wish.

If *dry\_run* is true, doesn't actually do anything that would affect the filesystem.

Byte-compilation is either done directly in this interpreter process with the standard `py_compile` module, or indirectly by writing a temporary script and executing it. Normally, you should let `byte_compile()` figure out to use direct compilation or not (see the source for details). The *direct* flag is used by the script generated in indirect mode; unless you know what you're doing, leave it set to `None`.

`distutils.util.rfc822_escape(header)`

Return a version of *header* escaped for inclusion in an **RFC 822** header, by ensuring there are 8 spaces space after each newline. Note that it does no other modification of the string.

## 11.13 `distutils.dist` — The Distribution class

This module provides the `Distribution` class, which represents the module distribution being built/installed/distributed.

## 11.14 `distutils.extension` — The Extension class

This module provides the `Extension` class, used to describe C/C++ extension modules in setup scripts.

## 11.15 `distutils.debug` — Distutils debug mode

This module provides the `DEBUG` flag.

## 11.16 `distutils.errors` — Distutils exceptions

Provides exceptions used by the Distutils modules. Note that Distutils modules may raise standard exceptions; in particular, `SystemExit` is usually raised for errors that are obviously the end-user's fault (eg. bad command-line arguments).

This module is safe to use in `from ... import *` mode; it only exports symbols whose names start with `Distutils` and end with `Error`.

## 11.17 `distutils.fancy_getopt` — Wrapper around the standard `getopt` module

This module provides a wrapper around the standard `getopt` module that provides the following additional features:

- short and long options are tied together
- options have help strings, so `fancy_getopt()` could potentially create a complete usage summary
- options set attributes of a passed-in object
- boolean options can have “negative aliases” — eg. if `--quiet` is the “negative alias” of `--verbose`, then `--quiet` on the command line sets `verbose` to false.

`distutils.fancy_getopt.fancy_getopt` (*options*, *negative\_opt*, *object*, *args*)

Wrapper function. *options* is a list of (*long\_option*, *short\_option*, *help\_string*) 3-tuples as described in the constructor for `FancyGetopt`. *negative\_opt* should be a dictionary mapping option names to option names, both the key and value should be in the *options* list. *object* is an object which will be used to store values (see the `getopt()` method of the `FancyGetopt` class). *args* is the argument list. Will use `sys.argv[1:]` if you pass `None` as *args*.

`distutils.fancy_getopt.wrap_text` (*text*, *width*)

Wraps *text* to less than *width* wide.

**class** `distutils.fancy_getopt.FancyGetopt` (*[option\_table=None]*)

The *option\_table* is a list of 3-tuples: (*long\_option*, *short\_option*, *help\_string*)

If an option takes an argument, its *long\_option* should have '=' appended; *short\_option* should just be a single character, no ':' in any case. *short\_option* should be `None` if a *long\_option* doesn't have a corresponding *short\_option*. All option tuples must have long options.

The `FancyGetopt` class provides the following methods:

`FancyGetopt.getopt` (*[args=None, object=None]*)

Parse command-line options in *args*. Store as attributes on *object*.

If *args* is `None` or not supplied, uses `sys.argv[1:]`. If *object* is `None` or not supplied, creates a new `OptionDummy` instance, stores option values there, and returns a tuple (*args*, *object*). If *object* is supplied, it is modified in place and `getopt()` just returns *args*; in both cases, the returned *args* is a modified copy of the passed-in *args* list, which is left untouched.

`FancyGetopt.get_option_order` ()

Returns the list of (*option*, *value*) tuples processed by the previous run of `getopt()` Raises `RuntimeError` if `getopt()` hasn't been called yet.

`FancyGetopt.generate_help` (*[header=None]*)

Generate help text (a list of strings, one per suggested line of output) from the option table for this `FancyGetopt` object.

If supplied, prints the supplied *header* at the top of the help.

## 11.18 `distutils.filelist` — The `FileList` class

This module provides the `FileList` class, used for poking about the filesystem and building lists of files.

## 11.19 `distutils.log` — Simple PEP 282-style logging

## 11.20 `distutils.spawn` — Spawn a sub-process

This module provides the `spawn()` function, a front-end to various platform-specific functions for launching another program in a sub-process. Also provides `find_executable()` to search the path for a given executable name.

## 11.21 `distutils.sysconfig` — System configuration information

The `distutils.sysconfig` module provides access to Python's low-level configuration information. The specific configuration variables available depend heavily on the platform and configuration. The specific variables depend on the build process for the specific version of Python being run; the variables are those found in the `Makefile` and configuration header that are installed with Python on Unix systems. The configuration header is called `pyconfig.h` for Python versions starting with 2.2, and `config.h` for earlier versions of Python.

Some additional functions are provided which perform some useful manipulations for other parts of the `distutils` package.

`distutils.sysconfig.PREFIX`

The result of `os.path.normpath(sys.prefix)`.

`distutils.sysconfig.EXEC_PREFIX`

The result of `os.path.normpath(sys.exec_prefix)`.

`distutils.sysconfig.get_config_var(name)`

Return the value of a single variable. This is equivalent to `get_config_vars().get(name)`.

`distutils.sysconfig.get_config_vars(...)`

Return a set of variable definitions. If there are no arguments, this returns a dictionary mapping names of configuration variables to values. If arguments are provided, they should be strings, and the return value will be a sequence giving the associated values. If a given name does not have a corresponding value, `None` will be included for that variable.

`distutils.sysconfig.get_config_h_filename()`

Return the full path name of the configuration header. For Unix, this will be the header generated by the **configure** script; for other platforms the header will have been supplied directly by the Python source distribution. The file is a platform-specific text file.

`distutils.sysconfig.get_makefile_filename()`

Return the full path name of the `Makefile` used to build Python. For Unix, this will be a file generated by the **configure** script; the meaning for other platforms will vary. The file is a platform-specific text file, if it exists. This function is only useful on POSIX platforms.

`distutils.sysconfig.get_python_inc([plat_specific[, prefix]])`

Return the directory for either the general or platform-dependent C include files. If `plat_specific` is true, the platform-dependent include directory is returned; if false or omitted, the platform-independent directory is returned. If `prefix` is given, it is used as either the prefix instead of `PREFIX`, or as the exec-prefix instead of `EXEC_PREFIX` if `plat_specific` is true.

`distutils.sysconfig.get_python_lib([plat_specific[, standard_lib[, prefix]]])`

Return the directory for either the general or platform-dependent library installation. If `plat_specific` is true, the platform-dependent include directory is returned; if false or omitted, the platform-independent directory is returned. If `prefix` is given, it is used as either the prefix instead of `PREFIX`, or as the exec-prefix instead of `EXEC_PREFIX` if `plat_specific` is true. If `standard_lib` is true, the directory for the standard library is returned rather than the directory for the installation of third-party extensions.

The following function is only intended for use within the `distutils` package.

`distutils.sysconfig.customize_compiler(compiler)`

Do any platform-specific customization of a `distutils.ccompiler.CCompiler` instance.

This function is only needed on Unix at this time, but should be called consistently to support forward-compatibility. It inserts the information that varies across Unix flavors and is stored in Python's `Makefile`. This information includes the selected compiler, compiler and linker options, and the extension used by the linker for shared objects.

This function is even more special-purpose, and should only be used from Python's own build procedures.

`distutils.sysconfig.set_python_build()`

Inform the `distutils.sysconfig` module that it is being used as part of the build process for Python.

This changes a lot of relative locations for files, allowing them to be located in the build area rather than in an installed Python.

## 11.22 `distutils.text_file` — The `TextFile` class

This module provides the `TextFile` class, which gives an interface to text files that (optionally) takes care of stripping comments, ignoring blank lines, and joining lines with backslashes.

**class** `distutils.text_file.TextFile` (`[filename=None, file=None, **options]`)

This class provides a file-like object that takes care of all the things you commonly want to do when processing a text file that has some line-by-line syntax: strip comments (as long as `#` is your comment character), skip blank lines, join adjacent lines by escaping the newline (ie. backslash at end of line), strip leading and/or trailing whitespace. All of these are optional and independently controllable.

The class provides a `warn()` method so you can generate warning messages that report physical line number, even if the logical line in question spans multiple physical lines. Also provides `unreadline()` for implementing line-at-a-time lookahead.

`TextFile` instances are create with either `filename`, `file`, or both. `RuntimeError` is raised if both are `None`. `filename` should be a string, and `file` a file object (or something that provides `readline()` and `close()` methods). It is recommended that you supply at least `filename`, so that `TextFile` can include it in warning messages. If `file` is not supplied, `TextFile` creates its own using the `open()` built-in function.

The options are all boolean, and affect the values returned by `readline()`

| option name                 | description                                                                                                                                                                                                                                                               | default |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| <code>strip_comments</code> | strip from ' <code>#</code> ' to end-of-line, as well as any whitespace leading up to the ' <code>#</code> ' —unless it is escaped by a backslash                                                                                                                         | true    |
| <code>lstrip_ws</code>      | strip leading whitespace from each line before returning it                                                                                                                                                                                                               | false   |
| <code>rstrip_ws</code>      | strip trailing whitespace (including line terminator!) from each line before returning it.                                                                                                                                                                                | true    |
| <code>skip_blanks</code>    | skip lines that are empty *after* stripping comments and whitespace. (If both <code>lstrip_ws</code> and <code>rstrip_ws</code> are false, then some lines may consist of solely whitespace: these will *not* be skipped, even if <code>skip_blanks</code> is true.)      | true    |
| <code>join_lines</code>     | if a backslash is the last non-newline character on a line after stripping comments and whitespace, join the following line to it to form one logical line; if N consecutive lines end with a backslash, then N+1 physical lines will be joined to form one logical line. | false   |
| <code>collapse_join</code>  | strip leading whitespace from lines that are joined to their predecessor; only matters if ( <code>join_lines</code> and not <code>lstrip_ws</code> )                                                                                                                      | false   |

Note that since `rstrip_ws` can strip the trailing newline, the semantics of `readline()` must differ from those of the built-in file object's `readline()` method! In particular, `readline()` returns `None` for end-of-file: an empty string might just be a blank line (or an all-whitespace line), if `rstrip_ws` is true but `skip_blanks` is not.

**open** (*filename*)

Open a new file *filename*. This overrides any *file* or *filename* constructor arguments.

**close** ()

Close the current file and forget everything we know about it (including the filename and the current line number).

**warn** (*msg* [, *line=None* ])

Print (to stderr) a warning message tied to the current logical line in the current file. If the current logical line in the file spans multiple physical lines, the warning refers to the whole range, such as "lines 3-5". If *line* is supplied, it overrides the current line number; it may be a list or tuple to indicate a range of physical lines, or an integer for a single physical line.

**readline** ()

Read and return a single logical line from the current file (or from an internal buffer if lines have previously been “unread” with `unreadline()`). If the *join\_lines* option is true, this may involve reading multiple physical lines concatenated into a single string. Updates the current line number, so calling `warn()` after `readline()` emits a warning about the physical line(s) just read. Returns None on end-of-file, since the empty string can occur if *rstrip\_ws* is true but *strip\_blanks* is not.

**readlines** ()

Read and return the list of all logical lines remaining in the current file. This updates the current line number to the last line of the file.

**unreadline** (*line*)

Push *line* (a string) onto an internal buffer that will be checked by future `readline()` calls. Handy for implementing a parser with line-at-a-time lookahead. Note that lines that are “unread” with `unreadline()` are not subsequently re-cleansed (whitespace stripped, or whatever) when read with `readline()`. If multiple calls are made to `unreadline()` before a call to `readline()`, the lines will be returned most in most recent first order.

## 11.23 `distutils.version` — Version number classes

## 11.24 `distutils.cmd` — Abstract base class for Distutils commands

This module supplies the abstract base class `Command`.

**class** `distutils.cmd.Command` (*dist*)

Abstract base class for defining command classes, the “worker bees” of the Distutils. A useful analogy for command classes is to think of them as subroutines with local variables called *options*. The options are declared in `initialize_options()` and defined (given their final values) in `finalize_options()`, both of which must be defined by every command class. The distinction between the two is necessary because option values might come from the outside world (command line, config file, ...), and any options dependent on other options must be computed after these outside influences have been processed — hence `finalize_options()`. The body of the subroutine, where it does all its work based on the values of its options, is the `run()` method, which must also be implemented by every command class.

The class constructor takes a single argument *dist*, a `Distribution` instance.

## 11.25 Creating a new Distutils command

This section outlines the steps to create a new Distutils command.

A new command lives in a module in the `distutils.command` package. There is a sample template in that directory called `command_template`. Copy this file to a new module with the same name as the new command you're implementing. This module should implement a class with the same name as the module (and the command). So, for instance, to create the command `peel_banana` (so that users can run `setup.py peel_banana`), you'd copy `command_template` to `distutils/command/peel_banana.py`, then edit it so that it's implementing the class `peel_banana`, a subclass of `distutils.cmd.Command`.

Subclasses of `Command` must define the following methods.

`Command.initialize_options()`

Set default values for all the options that this command supports. Note that these defaults may be overridden by other commands, by the setup script, by config files, or by the command-line. Thus, this is not the place to code dependencies between options; generally, `initialize_options()` implementations are just a bunch of `self.foo = None` assignments.

`Command.finalize_options()`

Set final values for all the options that this command supports. This is always called as late as possible, ie. after any option assignments from the command-line or from other commands have been done. Thus, this is the place to code option dependencies: if `foo` depends on `bar`, then it is safe to set `foo` from `bar` as long as `foo` still has the same value it was assigned in `initialize_options()`.

`Command.run()`

A command's raison d'être: carry out the action it exists to perform, controlled by the options initialized in `initialize_options()`, customized by other commands, the setup script, the command-line, and config files, and finalized in `finalize_options()`. All terminal output and filesystem interaction should be done by `run()`.

`Command.sub_commands`

`sub_commands` formalizes the notion of a “family” of commands, e.g. `install` as the parent with sub-commands `install_lib`, `install_headers`, etc. The parent of a family of commands defines `sub_commands` as a class attribute; it's a list of 2-tuples (`command_name`, `predicate`), with `command_name` a string and `predicate` a function, a string or `None`. `predicate` is a method of the parent command that determines whether the corresponding command is applicable in the current situation. (E.g. `install_headers` is only applicable if we have any C header files to install.) If `predicate` is `None`, that command is always applicable.

`sub_commands` is usually defined at the *end* of a class, because predicates can be methods of the class, so they must already have been defined. The canonical example is the `install` command.

**11.26 `distutils.command` — Individual Distutils commands****11.27 `distutils.command.bdist` — Build a binary installer****11.28 `distutils.command.bdist_packager` — Abstract base class for packagers****11.29 `distutils.command.bdist_dumb` — Build a “dumb” installer****11.30 `distutils.command.bdist_msi` — Build a Microsoft Installer binary package**

**class** `distutils.command.bdist_msi.bdist_msi`

Builds a *Windows Installer* (.msi) binary package.

In most cases, the `bdist_msi` installer is a better choice than the `bdist_wininst` installer, because it provides better support for Win64 platforms, allows administrators to perform non-interactive installations, and allows installation through group policies.



- 11.31** `distutils.command.bdist_rpm` — Build a binary distribution as a Redhat RPM and SRPM
- 11.32** `distutils.command.bdist_wininst` — Build a Windows installer
- 11.33** `distutils.command.sdist` — Build a source distribution
- 11.34** `distutils.command.build` — Build all files of a package
- 11.35** `distutils.command.build_clib` — Build any C libraries in a package
- 11.36** `distutils.command.build_ext` — Build any extensions in a package
- 11.37** `distutils.command.build_py` — Build the .py/.pyc files of a package
- 11.38** `distutils.command.build_scripts` — Build the scripts of a package
- 11.39** `distutils.command.clean` — Clean a package build area
- 11.40** `distutils.command.config` — Perform package configuration
- 11.41** `distutils.command.install` — Install a package
- 11.42** `distutils.command.install_data` — Install data files from a package
- 11.43** `distutils.command.install_headers` — Install C/C++ header files from a package
- 11.44** `distutils.command.install_lib` — Install library files from a package
- 11.45** `distutils.command.install_scripts` — Install script files from a package
- 11.31.** `distutils.command.bdist_rpm` — Build a binary distribution as a Redhat RPM and SRPM
- 11.46** `distutils.command.register` — Register a module with the

## 11.47 `distutils.command.check` — Check the meta-data of a package

The `check` command performs some tests on the meta-data of a package. For example, it verifies that all required meta-data are provided as the arguments passed to the `setup()` function.

---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**. . .** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See [PEP 302](#) for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to 2 in contrast to the 2.75 returned by float true division. Note that `(-11) // 4` is -3 because that is -2.75 rounded *downward*. See [PEP 238](#).

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to 2. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to 2.75. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

# ABOUT THESE DOCUMENTS

These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

| Release        | Derived from | Year      | Owner      | GPL compatible? |
|----------------|--------------|-----------|------------|-----------------|
| 0.9.0 thru 1.2 | n/a          | 1991-1995 | CWI        | yes             |
| 1.3 thru 1.5.2 | 1.2          | 1995-1999 | CNRI       | yes             |
| 1.6            | 1.5.2        | 2000      | CNRI       | no              |
| 2.0            | 1.6          | 2000      | BeOpen.com | no              |
| 1.6.1          | 1.6          | 2001      | CNRI       | no              |
| 2.1            | 2.0+1.6.1    | 2001      | PSF        | no              |
| 2.0.1          | 2.0+1.6.1    | 2001      | PSF        | yes             |
| 2.1.1          | 2.1+2.0.1    | 2001      | PSF        | yes             |
| 2.2            | 2.1.1        | 2001      | PSF        | yes             |
| 2.1.2          | 2.1.1        | 2002      | PSF        | yes             |
| 2.1.3          | 2.1.2        | 2002      | PSF        | yes             |
| 2.2.1          | 2.2          | 2002      | PSF        | yes             |
| 2.2.2          | 2.2.1        | 2002      | PSF        | yes             |
| 2.2.3          | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3            | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3.1          | 2.3          | 2002-2003 | PSF        | yes             |
| 2.3.2          | 2.3.1        | 2003      | PSF        | yes             |
| 2.3.3          | 2.3.2        | 2003      | PSF        | yes             |
| 2.3.4          | 2.3.3        | 2004      | PSF        | yes             |
| 2.3.5          | 2.3.4        | 2005      | PSF        | yes             |
| 2.4            | 2.3          | 2004      | PSF        | yes             |

Continued on next page

**Table C.1 – continued from previous page**

|       |       |      |     |     |
|-------|-------|------|-----|-----|
| 2.4.1 | 2.4   | 2005 | PSF | yes |
| 2.4.2 | 2.4.1 | 2005 | PSF | yes |
| 2.4.3 | 2.4.2 | 2006 | PSF | yes |
| 2.4.4 | 2.4.3 | 2006 | PSF | yes |
| 2.5   | 2.4   | 2006 | PSF | yes |
| 2.5.1 | 2.5   | 2007 | PSF | yes |
| 2.5.2 | 2.5.1 | 2008 | PSF | yes |
| 2.5.3 | 2.5.2 | 2008 | PSF | yes |
| 2.6   | 2.5   | 2008 | PSF | yes |
| 2.6.1 | 2.6   | 2008 | PSF | yes |
| 2.6.2 | 2.6.1 | 2009 | PSF | yes |
| 2.6.3 | 2.6.2 | 2009 | PSF | yes |
| 2.6.4 | 2.6.3 | 2010 | PSF | yes |
| 2.7   | 2.6   | 2010 | PSF | yes |

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## C.3 Licenses and Acknowledgements for Incorporated Software

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### C.3.1 Mersenne Twister

The `_random` module includes code based on a download from <http://www.math.keio.ac.jp/matsumoto/MT2002/emt19937ar.html>. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.  
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)  
or init_by_array(init_key, key_length).
```

```
Copyright (C) 1997 - 2002, Makoto Matsumoto and Takuji Nishimura,  
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```

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Any feedback is very welcome.  
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```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
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```

```
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The original and principal author of md5.h is L. Peter Deutsch
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that follows (in reverse chronological order):
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```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
           references to Ghostscript; clarified derivation from RFC 1321;
           now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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Modified by Jack Jansen, CWI, July 1995:

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# Extending and Embedding Python

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: [docs@python.org](mailto:docs@python.org)



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This document describes how to write modules in C or C++ to extend the Python interpreter with new modules. Those modules can define new functions but also new object types and their methods. The document also describes how to embed the Python interpreter in another application, for use as an extension language. Finally, it shows how to compile and link extension modules so that they can be loaded dynamically (at run time) into the interpreter, if the underlying operating system supports this feature.

This document assumes basic knowledge about Python. For an informal introduction to the language, see *tutorial-index*. *reference-index* gives a more formal definition of the language. *library-index* documents the existing object types, functions and modules (both built-in and written in Python) that give the language its wide application range.

For a detailed description of the whole Python/C API, see the separate *c-api-index*.



# EXTENDING PYTHON WITH C OR C++

It is quite easy to add new built-in modules to Python, if you know how to program in C. Such *extension modules* can do two things that can't be done directly in Python: they can implement new built-in object types, and they can call C library functions and system calls.

To support extensions, the Python API (Application Programmers Interface) defines a set of functions, macros and variables that provide access to most aspects of the Python run-time system. The Python API is incorporated in a C source file by including the header `"Python.h"`.

The compilation of an extension module depends on its intended use as well as on your system setup; details are given in later chapters.

Do note that if your use case is calling C library functions or system calls, you should consider using the `ctypes` module rather than writing custom C code. Not only does `ctypes` let you write Python code to interface with C code, but it is more portable between implementations of Python than writing and compiling an extension module which typically ties you to CPython.

## 1.1 A Simple Example

Let's create an extension module called `spam` (the favorite food of Monty Python fans...) and let's say we want to create a Python interface to the C library function `system()`.<sup>1</sup> This function takes a null-terminated character string as argument and returns an integer. We want this function to be callable from Python as follows:

```
>>> import spam
>>> status = spam.system("ls -l")
```

Begin by creating a file `spammodule.c`. (Historically, if a module is called `spam`, the C file containing its implementation is called `spammodule.c`; if the module name is very long, like `spammify`, the module name can be just `spammify.c`.)

The first line of our file can be:

```
#include <Python.h>
```

which pulls in the Python API (you can add a comment describing the purpose of the module and a copyright notice if you like).

---

**Note:** Since Python may define some pre-processor definitions which affect the standard headers on some systems, you *must* include `Python.h` before any standard headers are included.

---

<sup>1</sup> An interface for this function already exists in the standard module `os` — it was chosen as a simple and straightforward example.

All user-visible symbols defined by `Python.h` have a prefix of `Py` or `PY`, except those defined in standard header files. For convenience, and since they are used extensively by the Python interpreter, "`Python.h`" includes a few standard header files: `<stdio.h>`, `<string.h>`, `<errno.h>`, and `<stdlib.h>`. If the latter header file does not exist on your system, it declares the functions `malloc()`, `free()` and `realloc()` directly.

The next thing we add to our module file is the C function that will be called when the Python expression `spam.system(string)` is evaluated (we'll see shortly how it ends up being called):

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    return Py_BuildValue("i", sts);
}
```

There is a straightforward translation from the argument list in Python (for example, the single expression `"ls -l"`) to the arguments passed to the C function. The C function always has two arguments, conventionally named *self* and *args*.

The *self* argument points to the module object for module-level functions; for a method it would point to the object instance.

The *args* argument will be a pointer to a Python tuple object containing the arguments. Each item of the tuple corresponds to an argument in the call's argument list. The arguments are Python objects — in order to do anything with them in our C function we have to convert them to C values. The function `PyArg_ParseTuple()` in the Python API checks the argument types and converts them to C values. It uses a template string to determine the required types of the arguments as well as the types of the C variables into which to store the converted values. More about this later.

`PyArg_ParseTuple()` returns true (nonzero) if all arguments have the right type and its components have been stored in the variables whose addresses are passed. It returns false (zero) if an invalid argument list was passed. In the latter case it also raises an appropriate exception so the calling function can return `NULL` immediately (as we saw in the example).

## 1.2 Intermezzo: Errors and Exceptions

An important convention throughout the Python interpreter is the following: when a function fails, it should set an exception condition and return an error value (usually a `NULL` pointer). Exceptions are stored in a static global variable inside the interpreter; if this variable is `NULL` no exception has occurred. A second global variable stores the “associated value” of the exception (the second argument to `raise`). A third variable contains the stack traceback in case the error originated in Python code. These three variables are the C equivalents of the Python variables `sys.exc_type`, `sys.exc_value` and `sys.exc_traceback` (see the section on module `sys` in the Python Library Reference). It is important to know about them to understand how errors are passed around.

The Python API defines a number of functions to set various types of exceptions.

The most common one is `PyErr_SetString()`. Its arguments are an exception object and a C string. The exception object is usually a predefined object like `PyExc_ZeroDivisionError`. The C string indicates the cause of the error and is converted to a Python string object and stored as the “associated value” of the exception.

Another useful function is `PyErr_SetFromErrno()`, which only takes an exception argument and constructs the associated value by inspection of the global variable `errno`. The most general function is `PyErr_SetObject()`,

which takes two object arguments, the exception and its associated value. You don't need to `Py_INCREF()` the objects passed to any of these functions.

You can test non-destructively whether an exception has been set with `PyErr_Occurred()`. This returns the current exception object, or `NULL` if no exception has occurred. You normally don't need to call `PyErr_Occurred()` to see whether an error occurred in a function call, since you should be able to tell from the return value.

When a function *f* that calls another function *g* detects that the latter fails, *f* should itself return an error value (usually `NULL` or `-1`). It should *not* call one of the `PyErr_*()` functions — one has already been called by *g*. *f*'s caller is then supposed to also return an error indication to *its* caller, again *without* calling `PyErr_*()`, and so on — the most detailed cause of the error was already reported by the function that first detected it. Once the error reaches the Python interpreter's main loop, this aborts the currently executing Python code and tries to find an exception handler specified by the Python programmer.

(There are situations where a module can actually give a more detailed error message by calling another `PyErr_*()` function, and in such cases it is fine to do so. As a general rule, however, this is not necessary, and can cause information about the cause of the error to be lost: most operations can fail for a variety of reasons.)

To ignore an exception set by a function call that failed, the exception condition must be cleared explicitly by calling `PyErr_Clear()`. The only time C code should call `PyErr_Clear()` is if it doesn't want to pass the error on to the interpreter but wants to handle it completely by itself (possibly by trying something else, or pretending nothing went wrong).

Every failing `malloc()` call must be turned into an exception — the direct caller of `malloc()` (or `realloc()`) must call `PyErr_NoMemory()` and return a failure indicator itself. All the object-creating functions (for example, `PyInt_FromLong()`) already do this, so this note is only relevant to those who call `malloc()` directly.

Also note that, with the important exception of `PyArg_ParseTuple()` and friends, functions that return an integer status usually return a positive value or zero for success and `-1` for failure, like Unix system calls.

Finally, be careful to clean up garbage (by making `Py_XDECREF()` or `Py_DECREF()` calls for objects you have already created) when you return an error indicator!

The choice of which exception to raise is entirely yours. There are predeclared C objects corresponding to all built-in Python exceptions, such as `PyExc_ZeroDivisionError`, which you can use directly. Of course, you should choose exceptions wisely — don't use `PyExc_TypeError` to mean that a file couldn't be opened (that should probably be `PyExc_IOError`). If something's wrong with the argument list, the `PyArg_ParseTuple()` function usually raises `PyExc_TypeError`. If you have an argument whose value must be in a particular range or must satisfy other conditions, `PyExc_ValueError` is appropriate.

You can also define a new exception that is unique to your module. For this, you usually declare a static object variable at the beginning of your file:

```
static PyObject *SpamError;
```

and initialize it in your module's initialization function (`initspam()`) with an exception object (leaving out the error checking for now):

```
PyMODINIT_FUNC
initspam(void)
{
    PyObject *m;

    m = Py_InitModule("spam", SpamMethods);
    if (m == NULL)
        return;

    SpamError = PyErr_NewException("spam.error", NULL, NULL);
    Py_INCREF(SpamError);
```

```
PyModule_AddObject(m, "error", SpamError);
}
```

Note that the Python name for the exception object is `spam.error`. The `PyErr_NewException()` function may create a class with the base class being `Exception` (unless another class is passed in instead of `NULL`), described in *builtin-exceptions*.

Note also that the `SpamError` variable retains a reference to the newly created exception class; this is intentional! Since the exception could be removed from the module by external code, an owned reference to the class is needed to ensure that it will not be discarded, causing `SpamError` to become a dangling pointer. Should it become a dangling pointer, C code which raises the exception could cause a core dump or other unintended side effects.

We discuss the use of `PyMODINIT_FUNC` as a function return type later in this sample.

The `spam.error` exception can be raised in your extension module using a call to `PyErr_SetString()` as shown below:

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    if (sts < 0) {
        PyErr_SetString(SpamError, "System command failed");
        return NULL;
    }
    return PyLong_FromLong(sts);
}
```

### 1.3 Back to the Example

Going back to our example function, you should now be able to understand this statement:

```
if (!PyArg_ParseTuple(args, "s", &command))
    return NULL;
```

It returns `NULL` (the error indicator for functions returning object pointers) if an error is detected in the argument list, relying on the exception set by `PyArg_ParseTuple()`. Otherwise the string value of the argument has been copied to the local variable `command`. This is a pointer assignment and you are not supposed to modify the string to which it points (so in Standard C, the variable `command` should properly be declared as `const char *command`).

The next statement is a call to the Unix function `system()`, passing it the string we just got from `PyArg_ParseTuple()`:

```
sts = system(command);
```

Our `spam.system()` function must return the value of `sts` as a Python object. This is done using the function `Py_BuildValue()`, which is something like the inverse of `PyArg_ParseTuple()`: it takes a format string and an arbitrary number of C values, and returns a new Python object. More info on `Py_BuildValue()` is given later.

```
return Py_BuildValue("i", sts);
```

In this case, it will return an integer object. (Yes, even integers are objects on the heap in Python!)

If you have a C function that returns no useful argument (a function returning `void`), the corresponding Python function must return `None`. You need this idiom to do so (which is implemented by the `Py_RETURN_NONE` macro):

```
Py_INCREF(Py_None);
return Py_None;
```

`Py_None` is the C name for the special Python object `None`. It is a genuine Python object rather than a `NULL` pointer, which means “error” in most contexts, as we have seen.

## 1.4 The Module’s Method Table and Initialization Function

I promised to show how `spam_system()` is called from Python programs. First, we need to list its name and address in a “method table”:

```
static PyMethodDef SpamMethods[] = {
    ...
    {"system", spam_system, METH_VARARGS,
     "Execute a shell command."},
    ...
    {NULL, NULL, 0, NULL} /* Sentinel */
};
```

Note the third entry (`METH_VARARGS`). This is a flag telling the interpreter the calling convention to be used for the C function. It should normally always be `METH_VARARGS` or `METH_VARARGS | METH_KEYWORDS`; a value of 0 means that an obsolete variant of `PyArg_ParseTuple()` is used.

When using only `METH_VARARGS`, the function should expect the Python-level parameters to be passed in as a tuple acceptable for parsing via `PyArg_ParseTuple()`; more information on this function is provided below.

The `METH_KEYWORDS` bit may be set in the third field if keyword arguments should be passed to the function. In this case, the C function should accept a third `PyObject *` parameter which will be a dictionary of keywords. Use `PyArg_ParseTupleAndKeywords()` to parse the arguments to such a function.

The method table must be passed to the interpreter in the module’s initialization function. The initialization function must be named `initname()`, where *name* is the name of the module, and should be the only non-static item defined in the module file:

```
PyMODINIT_FUNC
initspam(void)
{
    (void) Py_InitModule("spam", SpamMethods);
}
```

Note that `PyMODINIT_FUNC` declares the function as `void` return type, declares any special linkage declarations required by the platform, and for C++ declares the function as `extern "C"`.

When the Python program imports module `spam` for the first time, `initspam()` is called. (See below for comments about embedding Python.) It calls `Py_InitModule()`, which creates a “module object” (which is inserted in the dictionary `sys.modules` under the key “spam”), and inserts built-in function objects into the newly created module based upon the table (an array of `PyMethodDef` structures) that was passed as its second argument. `Py_InitModule()` returns a pointer to the module object that it creates (which is unused here). It may abort with a fatal error for certain errors, or return `NULL` if the module could not be initialized satisfactorily.

When embedding Python, the `initspam()` function is not called automatically unless there’s an entry in the `_PyImport_Inittab` table. The easiest way to handle this is to statically initialize your statically-linked modules by directly calling `initspam()` after the call to `Py_Initialize()`:

```
int
main(int argc, char *argv[])
{
    /* Pass argv[0] to the Python interpreter */
    Py_SetProgramName(argv[0]);

    /* Initialize the Python interpreter.  Required. */
    Py_Initialize();

    /* Add a static module */
    initspam();
}
```

An example may be found in the file `Demo/embed/demo.c` in the Python source distribution.

---

**Note:** Removing entries from `sys.modules` or importing compiled modules into multiple interpreters within a process (or following a `fork()` without an intervening `exec()`) can create problems for some extension modules. Extension module authors should exercise caution when initializing internal data structures. Note also that the `reload()` function can be used with extension modules, and will call the module initialization function (`initspam()` in the example), but will not load the module again if it was loaded from a dynamically loadable object file (`.so` on Unix, `.dll` on Windows).

---

A more substantial example module is included in the Python source distribution as `Modules/xxmodule.c`. This file may be used as a template or simply read as an example.

## 1.5 Compilation and Linkage

There are two more things to do before you can use your new extension: compiling and linking it with the Python system. If you use dynamic loading, the details may depend on the style of dynamic loading your system uses; see the chapters about building extension modules (chapter *Building C and C++ Extensions with distutils*) and additional information that pertains only to building on Windows (chapter *Building C and C++ Extensions on Windows*) for more information about this.

If you can't use dynamic loading, or if you want to make your module a permanent part of the Python interpreter, you will have to change the configuration setup and rebuild the interpreter. Luckily, this is very simple on Unix: just place your file (`spammodule.c` for example) in the `Modules/` directory of an unpacked source distribution, add a line to the file `Modules/Setup.local` describing your file:

```
spam spammodule.o
```

and rebuild the interpreter by running **make** in the toplevel directory. You can also run **make** in the `Modules/` subdirectory, but then you must first rebuild `Makefile` there by running '**make Makefile**'. (This is necessary each time you change the `Setup` file.)

If your module requires additional libraries to link with, these can be listed on the line in the configuration file as well, for instance:

```
spam spammodule.o -lX11
```

## 1.6 Calling Python Functions from C

So far we have concentrated on making C functions callable from Python. The reverse is also useful: calling Python functions from C. This is especially the case for libraries that support so-called "callback" functions. If a C interface

makes use of callbacks, the equivalent Python often needs to provide a callback mechanism to the Python programmer; the implementation will require calling the Python callback functions from a C callback. Other uses are also imaginable.

Fortunately, the Python interpreter is easily called recursively, and there is a standard interface to call a Python function. (I won't dwell on how to call the Python parser with a particular string as input — if you're interested, have a look at the implementation of the `-c` command line option in `Modules/main.c` from the Python source code.)

Calling a Python function is easy. First, the Python program must somehow pass you the Python function object. You should provide a function (or some other interface) to do this. When this function is called, save a pointer to the Python function object (be careful to `Py_INCREF()` it!) in a global variable — or wherever you see fit. For example, the following function might be part of a module definition:

```
static PyObject *my_callback = NULL;

static PyObject *
my_set_callback(PyObject *dummy, PyObject *args)
{
    PyObject *result = NULL;
    PyObject *temp;

    if (PyArg_ParseTuple(args, "O:set_callback", &temp)) {
        if (!PyCallable_Check(temp)) {
            PyErr_SetString(PyExc_TypeError, "parameter must be callable");
            return NULL;
        }
        Py_XINCRREF(temp);          /* Add a reference to new callback */
        Py_XDECREF(my_callback);    /* Dispose of previous callback */
        my_callback = temp;         /* Remember new callback */
        /* Boilerplate to return "None" */
        Py_INCREF(Py_None);
        result = Py_None;
    }
    return result;
}
```

This function must be registered with the interpreter using the `METH_VARARGS` flag; this is described in section *The Module's Method Table and Initialization Function*. The `PyArg_ParseTuple()` function and its arguments are documented in section *Extracting Parameters in Extension Functions*.

The macros `Py_XINCRREF()` and `Py_XDECREF()` increment/decrement the reference count of an object and are safe in the presence of `NULL` pointers (but note that `temp` will not be `NULL` in this context). More info on them in section *Reference Counts*.

Later, when it is time to call the function, you call the C function `PyObject_CallObject()`. This function has two arguments, both pointers to arbitrary Python objects: the Python function, and the argument list. The argument list must always be a tuple object, whose length is the number of arguments. To call the Python function with no arguments, pass in `NULL`, or an empty tuple; to call it with one argument, pass a singleton tuple. `Py_BuildValue()` returns a tuple when its format string consists of zero or more format codes between parentheses. For example:

```
int arg;
PyObject *arglist;
PyObject *result;
...
arg = 123;
...
/* Time to call the callback */
```

```
arglist = Py_BuildValue("(i)", arg);
result = PyObject_CallObject(my_callback, arglist);
Py_DECREF(arglist);
```

`PyObject_CallObject()` returns a Python object pointer: this is the return value of the Python function. `PyObject_CallObject()` is “reference-count-neutral” with respect to its arguments. In the example a new tuple was created to serve as the argument list, which is `Py_DECREF()`-ed immediately after the call.

The return value of `PyObject_CallObject()` is “new”: either it is a brand new object, or it is an existing object whose reference count has been incremented. So, unless you want to save it in a global variable, you should somehow `Py_DECREF()` the result, even (especially!) if you are not interested in its value.

Before you do this, however, it is important to check that the return value isn't `NULL`. If it is, the Python function terminated by raising an exception. If the C code that called `PyObject_CallObject()` is called from Python, it should now return an error indication to its Python caller, so the interpreter can print a stack trace, or the calling Python code can handle the exception. If this is not possible or desirable, the exception should be cleared by calling `PyErr_Clear()`. For example:

```
if (result == NULL)
    return NULL; /* Pass error back */
...use result...
Py_DECREF(result);
```

Depending on the desired interface to the Python callback function, you may also have to provide an argument list to `PyObject_CallObject()`. In some cases the argument list is also provided by the Python program, through the same interface that specified the callback function. It can then be saved and used in the same manner as the function object. In other cases, you may have to construct a new tuple to pass as the argument list. The simplest way to do this is to call `Py_BuildValue()`. For example, if you want to pass an integral event code, you might use the following code:

```
PyObject *arglist;
...
arglist = Py_BuildValue("(l)", eventcode);
result = PyObject_CallObject(my_callback, arglist);
Py_DECREF(arglist);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DECREF(result);
```

Note the placement of `Py_DECREF(arglist)` immediately after the call, before the error check! Also note that strictly speaking this code is not complete: `Py_BuildValue()` may run out of memory, and this should be checked.

You may also call a function with keyword arguments by using `PyObject_Call()`, which supports arguments and keyword arguments. As in the above example, we use `Py_BuildValue()` to construct the dictionary.

```
PyObject *dict;
...
dict = Py_BuildValue("{s:i}", "name", val);
result = PyObject_Call(my_callback, NULL, dict);
Py_DECREF(dict);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DECREF(result);
```

## 1.7 Extracting Parameters in Extension Functions

The `PyArg_ParseTuple()` function is declared as follows:

```
int PyArg_ParseTuple(PyObject *arg, char *format, ...);
```

The *arg* argument must be a tuple object containing an argument list passed from Python to a C function. The *format* argument must be a format string, whose syntax is explained in *arg-parsing* in the Python/C API Reference Manual. The remaining arguments must be addresses of variables whose type is determined by the format string.

Note that while `PyArg_ParseTuple()` checks that the Python arguments have the required types, it cannot check the validity of the addresses of C variables passed to the call: if you make mistakes there, your code will probably crash or at least overwrite random bits in memory. So be careful!

Note that any Python object references which are provided to the caller are *borrowed* references; do not decrement their reference count!

Some example calls:

```
int ok;
int i, j;
long k, l;
const char *s;
int size;

ok = PyArg_ParseTuple(args, ""); /* No arguments */
    /* Python call: f() */

ok = PyArg_ParseTuple(args, "s", &s); /* A string */
    /* Possible Python call: f('whoops!') */

ok = PyArg_ParseTuple(args, "lls", &k, &l, &s); /* Two longs and a string */
    /* Possible Python call: f(1, 2, 'three') */

ok = PyArg_ParseTuple(args, "(ii)s#", &i, &j, &s, &size);
    /* A pair of ints and a string, whose size is also returned */
    /* Possible Python call: f((1, 2), 'three') */

{
    const char *file;
    const char *mode = "r";
    int bufsize = 0;
    ok = PyArg_ParseTuple(args, "s|si", &file, &mode, &bufsize);
    /* A string, and optionally another string and an integer */
    /* Possible Python calls:
        f('spam')
        f('spam', 'w')
        f('spam', 'wb', 100000) */
}

{
    int left, top, right, bottom, h, v;
    ok = PyArg_ParseTuple(args, "((ii)(ii))(ii)",
        &left, &top, &right, &bottom, &h, &v);
    /* A rectangle and a point */
    /* Possible Python call:
        f(((0, 0), (400, 300)), (10, 10)) */
}
```

```
{
    Py_complex c;
    ok = PyArg_ParseTuple(args, "D:myfunction", &c);
    /* a complex, also providing a function name for errors */
    /* Possible Python call: myfunction(1+2j) */
}
```

## 1.8 Keyword Parameters for Extension Functions

The `PyArg_ParseTupleAndKeywords()` function is declared as follows:

```
int PyArg_ParseTupleAndKeywords(PyObject *arg, PyObject *kwdict,
                                char *format, char *kwlist[], ...);
```

The *arg* and *format* parameters are identical to those of the `PyArg_ParseTuple()` function. The *kwdict* parameter is the dictionary of keywords received as the third parameter from the Python runtime. The *kwlist* parameter is a *NULL*-terminated list of strings which identify the parameters; the names are matched with the type information from *format* from left to right. On success, `PyArg_ParseTupleAndKeywords()` returns true, otherwise it returns false and raises an appropriate exception.

---

**Note:** Nested tuples cannot be parsed when using keyword arguments! Keyword parameters passed in which are not present in the *kwlist* will cause `TypeError` to be raised.

---

Here is an example module which uses keywords, based on an example by Geoff Philbrick ([philbrick@hks.com](mailto:philbrick@hks.com)):

```
#include "Python.h"

static PyObject *
keywdarg_parrot(PyObject *self, PyObject *args, PyObject *keywds)
{
    int voltage;
    char *state = "a stiff";
    char *action = "vooom";
    char *type = "Norwegian Blue";

    static char *kwlist[] = {"voltage", "state", "action", "type", NULL};

    if (!PyArg_ParseTupleAndKeywords(args, keywds, "i|sss", kwlist,
                                     &voltage, &state, &action, &type))
        return NULL;

    printf("-- This parrot wouldn't %s if you put %i Volts through it.\n",
           action, voltage);
    printf("-- Lovely plumage, the %s -- It's %s!\n", type, state);

    Py_INCREF(Py_None);

    return Py_None;
}

static PyMethodDef keywdarg_methods[] = {
    /* The cast of the function is necessary since PyCFunction values
     * only take two PyObject* parameters, and keywdarg_parrot() takes
```

```

        * three.
        */
        {"parrot", (PyCFunction)keywdarg_parrot, METH_VARARGS | METH_KEYWORDS,
         "Print a lovely skit to standard output."},
        {NULL, NULL, 0, NULL} /* sentinel */
    };

void
initkeywdarg(void)
{
    /* Create the module and add the functions */
    Py_InitModule("keywdarg", keywdarg_methods);
}

```

## 1.9 Building Arbitrary Values

This function is the counterpart to `PyArg_ParseTuple()`. It is declared as follows:

```
PyObject *Py_BuildValue(char *format, ...);
```

It recognizes a set of format units similar to the ones recognized by `PyArg_ParseTuple()`, but the arguments (which are input to the function, not output) must not be pointers, just values. It returns a new Python object, suitable for returning from a C function called from Python.

One difference with `PyArg_ParseTuple()`: while the latter requires its first argument to be a tuple (since Python argument lists are always represented as tuples internally), `Py_BuildValue()` does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns `None`; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

Examples (to the left the call, to the right the resulting Python value):

|                                                                     |                                       |
|---------------------------------------------------------------------|---------------------------------------|
| <code>Py_BuildValue("")</code>                                      | <code>None</code>                     |
| <code>Py_BuildValue("i", 123)</code>                                | <code>123</code>                      |
| <code>Py_BuildValue("iii", 123, 456, 789)</code>                    | <code>(123, 456, 789)</code>          |
| <code>Py_BuildValue("s", "hello")</code>                            | <code>'hello'</code>                  |
| <code>Py_BuildValue("ss", "hello", "world")</code>                  | <code>('hello', 'world')</code>       |
| <code>Py_BuildValue("s#", "hello", 4)</code>                        | <code>'hell'</code>                   |
| <code>Py_BuildValue("()")</code>                                    | <code>()</code>                       |
| <code>Py_BuildValue("(i)", 123)</code>                              | <code>(123,)</code>                   |
| <code>Py_BuildValue("(ii)", 123, 456)</code>                        | <code>(123, 456)</code>               |
| <code>Py_BuildValue("(i,i)", 123, 456)</code>                       | <code>(123, 456)</code>               |
| <code>Py_BuildValue("[i,i]", 123, 456)</code>                       | <code>[123, 456]</code>               |
| <code>Py_BuildValue("{s:i,s:i}",<br/>"abc", 123, "def", 456)</code> | <code>{'abc': 123, 'def': 456}</code> |
| <code>Py_BuildValue("((ii)(ii))(ii)",<br/>1, 2, 3, 4, 5, 6)</code>  | <code>((1, 2), (3, 4)), (5, 6)</code> |

## 1.10 Reference Counts

In languages like C or C++, the programmer is responsible for dynamic allocation and deallocation of memory on the heap. In C, this is done using the functions `malloc()` and `free()`. In C++, the operators `new` and `delete` are used with essentially the same meaning and we'll restrict the following discussion to the C case.

Every block of memory allocated with `malloc()` should eventually be returned to the pool of available memory by exactly one call to `free()`. It is important to call `free()` at the right time. If a block's address is forgotten but `free()` is not called for it, the memory it occupies cannot be reused until the program terminates. This is called a *memory leak*. On the other hand, if a program calls `free()` for a block and then continues to use the block, it creates a conflict with re-use of the block through another `malloc()` call. This is called *using freed memory*. It has the same bad consequences as referencing uninitialized data — core dumps, wrong results, mysterious crashes.

Common causes of memory leaks are unusual paths through the code. For instance, a function may allocate a block of memory, do some calculation, and then free the block again. Now a change in the requirements for the function may add a test to the calculation that detects an error condition and can return prematurely from the function. It's easy to forget to free the allocated memory block when taking this premature exit, especially when it is added later to the code. Such leaks, once introduced, often go undetected for a long time: the error exit is taken only in a small fraction of all calls, and most modern machines have plenty of virtual memory, so the leak only becomes apparent in a long-running process that uses the leaking function frequently. Therefore, it's important to prevent leaks from happening by having a coding convention or strategy that minimizes this kind of errors.

Since Python makes heavy use of `malloc()` and `free()`, it needs a strategy to avoid memory leaks as well as the use of freed memory. The chosen method is called *reference counting*. The principle is simple: every object contains a counter, which is incremented when a reference to the object is stored somewhere, and which is decremented when a reference to it is deleted. When the counter reaches zero, the last reference to the object has been deleted and the object is freed.

An alternative strategy is called *automatic garbage collection*. (Sometimes, reference counting is also referred to as a garbage collection strategy, hence my use of “automatic” to distinguish the two.) The big advantage of automatic garbage collection is that the user doesn't need to call `free()` explicitly. (Another claimed advantage is an improvement in speed or memory usage — this is no hard fact however.) The disadvantage is that for C, there is no truly portable automatic garbage collector, while reference counting can be implemented portably (as long as the functions `malloc()` and `free()` are available — which the C Standard guarantees). Maybe some day a sufficiently portable automatic garbage collector will be available for C. Until then, we'll have to live with reference counts.

While Python uses the traditional reference counting implementation, it also offers a cycle detector that works to detect reference cycles. This allows applications to not worry about creating direct or indirect circular references; these are the weakness of garbage collection implemented using only reference counting. Reference cycles consist of objects which contain (possibly indirect) references to themselves, so that each object in the cycle has a reference count which is non-zero. Typical reference counting implementations are not able to reclaim the memory belonging to any objects in a reference cycle, or referenced from the objects in the cycle, even though there are no further references to the cycle itself.

The cycle detector is able to detect garbage cycles and can reclaim them so long as there are no finalizers implemented in Python (`__del__()` methods). When there are such finalizers, the detector exposes the cycles through the `gc` module (specifically, the `garbage` variable in that module). The `gc` module also exposes a way to run the detector (the `collect()` function), as well as configuration interfaces and the ability to disable the detector at runtime. The cycle detector is considered an optional component; though it is included by default, it can be disabled at build time using the `--without-cycle-gc` option to the **configure** script on Unix platforms (including Mac OS X) or by removing the definition of `WITH_CYCLE_GC` in the `pyconfig.h` header on other platforms. If the cycle detector is disabled in this way, the `gc` module will not be available.

### 1.10.1 Reference Counting in Python

There are two macros, `Py_INCREF(x)` and `Py_DECREF(x)`, which handle the incrementing and decrementing of the reference count. `Py_DECREF()` also frees the object when the count reaches zero. For flexibility, it doesn't call `free()` directly — rather, it makes a call through a function pointer in the object's *type object*. For this purpose (and others), every object also contains a pointer to its type object.

The big question now remains: when to use `Py_INCREF(x)` and `Py_DECREF(x)`? Let's first introduce some terms. Nobody “owns” an object; however, you can *own a reference* to an object. An object's reference count is now

defined as the number of owned references to it. The owner of a reference is responsible for calling `Py_DECREF()` when the reference is no longer needed. Ownership of a reference can be transferred. There are three ways to dispose of an owned reference: pass it on, store it, or call `Py_DECREF()`. Forgetting to dispose of an owned reference creates a memory leak.

It is also possible to *borrow*<sup>2</sup> a reference to an object. The borrower of a reference should not call `Py_DECREF()`. The borrower must not hold on to the object longer than the owner from which it was borrowed. Using a borrowed reference after the owner has disposed of it risks using freed memory and should be avoided completely.<sup>3</sup>

The advantage of borrowing over owning a reference is that you don't need to take care of disposing of the reference on all possible paths through the code — in other words, with a borrowed reference you don't run the risk of leaking when a premature exit is taken. The disadvantage of borrowing over owning is that there are some subtle situations where in seemingly correct code a borrowed reference can be used after the owner from which it was borrowed has in fact disposed of it.

A borrowed reference can be changed into an owned reference by calling `Py_INCREF()`. This does not affect the status of the owner from which the reference was borrowed — it creates a new owned reference, and gives full owner responsibilities (the new owner must dispose of the reference properly, as well as the previous owner).

### 1.10.2 Ownership Rules

Whenever an object reference is passed into or out of a function, it is part of the function's interface specification whether ownership is transferred with the reference or not.

Most functions that return a reference to an object pass on ownership with the reference. In particular, all functions whose function it is to create a new object, such as `PyInt_FromLong()` and `Py_BuildValue()`, pass ownership to the receiver. Even if the object is not actually new, you still receive ownership of a new reference to that object. For instance, `PyInt_FromLong()` maintains a cache of popular values and can return a reference to a cached item.

Many functions that extract objects from other objects also transfer ownership with the reference, for instance `PyObject_GetAttrString()`. The picture is less clear, here, however, since a few common routines are exceptions: `PyTuple_GetItem()`, `PyList_GetItem()`, `PyDict_GetItem()`, and `PyDict_GetItemString()` all return references that you borrow from the tuple, list or dictionary.

The function `PyImport_AddModule()` also returns a borrowed reference, even though it may actually create the object it returns: this is possible because an owned reference to the object is stored in `sys.modules`.

When you pass an object reference into another function, in general, the function borrows the reference from you — if it needs to store it, it will use `Py_INCREF()` to become an independent owner. There are exactly two important exceptions to this rule: `PyTuple_SetItem()` and `PyList_SetItem()`. These functions take over ownership of the item passed to them — even if they fail! (Note that `PyDict_SetItem()` and friends don't take over ownership — they are “normal.”)

When a C function is called from Python, it borrows references to its arguments from the caller. The caller owns a reference to the object, so the borrowed reference's lifetime is guaranteed until the function returns. Only when such a borrowed reference must be stored or passed on, it must be turned into an owned reference by calling `Py_INCREF()`.

The object reference returned from a C function that is called from Python must be an owned reference — ownership is transferred from the function to its caller.

### 1.10.3 Thin Ice

There are a few situations where seemingly harmless use of a borrowed reference can lead to problems. These all have to do with implicit invocations of the interpreter, which can cause the owner of a reference to dispose of it.

<sup>2</sup> The metaphor of “borrowing” a reference is not completely correct: the owner still has a copy of the reference.

<sup>3</sup> Checking that the reference count is at least 1 **does not work** — the reference count itself could be in freed memory and may thus be reused for another object!

The first and most important case to know about is using `Py_DECREF()` on an unrelated object while borrowing a reference to a list item. For instance:

```
void
bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    PyList_SetItem(list, 1, PyInt_FromLong(0L));
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

This function first borrows a reference to `list[0]`, then replaces `list[1]` with the value 0, and finally prints the borrowed reference. Looks harmless, right? But it's not!

Let's follow the control flow into `PyList_SetItem()`. The list owns references to all its items, so when item 1 is replaced, it has to dispose of the original item 1. Now let's suppose the original item 1 was an instance of a user-defined class, and let's further suppose that the class defined a `__del__()` method. If this class instance has a reference count of 1, disposing of it will call its `__del__()` method.

Since it is written in Python, the `__del__()` method can execute arbitrary Python code. Could it perhaps do something to invalidate the reference to `item` in `bug()`? You bet! Assuming that the list passed into `bug()` is accessible to the `__del__()` method, it could execute a statement to the effect of `del list[0]`, and assuming this was the last reference to that object, it would free the memory associated with it, thereby invalidating `item`.

The solution, once you know the source of the problem, is easy: temporarily increment the reference count. The correct version of the function reads:

```
void
no_bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    Py_INCREF(item);
    PyList_SetItem(list, 1, PyInt_FromLong(0L));
    PyObject_Print(item, stdout, 0);
    Py_DECREF(item);
}
```

This is a true story. An older version of Python contained variants of this bug and someone spent a considerable amount of time in a C debugger to figure out why his `__del__()` methods would fail...

The second case of problems with a borrowed reference is a variant involving threads. Normally, multiple threads in the Python interpreter can't get in each other's way, because there is a global lock protecting Python's entire object space. However, it is possible to temporarily release this lock using the macro `Py_BEGIN_ALLOW_THREADS`, and to re-acquire it using `Py_END_ALLOW_THREADS`. This is common around blocking I/O calls, to let other threads use the processor while waiting for the I/O to complete. Obviously, the following function has the same problem as the previous one:

```
void
bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);
    Py_BEGIN_ALLOW_THREADS
    ...some blocking I/O call...
    Py_END_ALLOW_THREADS
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

## 1.10.4 NULL Pointers

In general, functions that take object references as arguments do not expect you to pass them *NULL* pointers, and will dump core (or cause later core dumps) if you do so. Functions that return object references generally return *NULL* only to indicate that an exception occurred. The reason for not testing for *NULL* arguments is that functions often pass the objects they receive on to other function — if each function were to test for *NULL*, there would be a lot of redundant tests and the code would run more slowly.

It is better to test for *NULL* only at the “source:” when a pointer that may be *NULL* is received, for example, from `malloc()` or from a function that may raise an exception.

The macros `Py_INCREF()` and `Py_DECREF()` do not check for *NULL* pointers — however, their variants `Py_XINCREF()` and `Py_XDECREF()` do.

The macros for checking for a particular object type (`PyType_Check()`) don’t check for *NULL* pointers — again, there is much code that calls several of these in a row to test an object against various different expected types, and this would generate redundant tests. There are no variants with *NULL* checking.

The C function calling mechanism guarantees that the argument list passed to C functions (`args` in the examples) is never *NULL* — in fact it guarantees that it is always a tuple.<sup>4</sup>

It is a severe error to ever let a *NULL* pointer “escape” to the Python user.

## 1.11 Writing Extensions in C++

It is possible to write extension modules in C++. Some restrictions apply. If the main program (the Python interpreter) is compiled and linked by the C compiler, global or static objects with constructors cannot be used. This is not a problem if the main program is linked by the C++ compiler. Functions that will be called by the Python interpreter (in particular, module initialization functions) have to be declared using `extern "C"`. It is unnecessary to enclose the Python header files in `extern "C" { ... }` — they use this form already if the symbol `__cplusplus` is defined (all recent C++ compilers define this symbol).

## 1.12 Providing a C API for an Extension Module

Many extension modules just provide new functions and types to be used from Python, but sometimes the code in an extension module can be useful for other extension modules. For example, an extension module could implement a type “collection” which works like lists without order. Just like the standard Python list type has a C API which permits extension modules to create and manipulate lists, this new collection type should have a set of C functions for direct manipulation from other extension modules.

At first sight this seems easy: just write the functions (without declaring them `static`, of course), provide an appropriate header file, and document the C API. And in fact this would work if all extension modules were always linked statically with the Python interpreter. When modules are used as shared libraries, however, the symbols defined in one module may not be visible to another module. The details of visibility depend on the operating system; some systems use one global namespace for the Python interpreter and all extension modules (Windows, for example), whereas others require an explicit list of imported symbols at module link time (AIX is one example), or offer a choice of different strategies (most Unices). And even if symbols are globally visible, the module whose functions one wishes to call might not have been loaded yet!

Portability therefore requires not to make any assumptions about symbol visibility. This means that all symbols in extension modules should be declared `static`, except for the module’s initialization function, in order to avoid name clashes with other extension modules (as discussed in section *The Module’s Method Table and Initialization Function*). And it means that symbols that *should* be accessible from other extension modules must be exported in a different way.

<sup>4</sup> These guarantees don’t hold when you use the “old” style calling convention — this is still found in much existing code.

Python provides a special mechanism to pass C-level information (pointers) from one extension module to another one: Capsules. A Capsule is a Python data type which stores a pointer (`void *`). Capsules can only be created and accessed via their C API, but they can be passed around like any other Python object. In particular, they can be assigned to a name in an extension module's namespace. Other extension modules can then import this module, retrieve the value of this name, and then retrieve the pointer from the Capsule.

There are many ways in which Capsules can be used to export the C API of an extension module. Each function could get its own Capsule, or all C API pointers could be stored in an array whose address is published in a Capsule. And the various tasks of storing and retrieving the pointers can be distributed in different ways between the module providing the code and the client modules.

Whichever method you choose, it's important to name your Capsules properly. The function `PyCapsule_New()` takes a name parameter (`const char *`); you're permitted to pass in a `NULL` name, but we strongly encourage you to specify a name. Properly named Capsules provide a degree of runtime type-safety; there is no feasible way to tell one unnamed Capsule from another.

In particular, Capsules used to expose C APIs should be given a name following this convention:

```
modulename.attributename
```

The convenience function `PyCapsule_Import()` makes it easy to load a C API provided via a Capsule, but only if the Capsule's name matches this convention. This behavior gives C API users a high degree of certainty that the Capsule they load contains the correct C API.

The following example demonstrates an approach that puts most of the burden on the writer of the exporting module, which is appropriate for commonly used library modules. It stores all C API pointers (just one in the example!) in an array of `void` pointers which becomes the value of a Capsule. The header file corresponding to the module provides a macro that takes care of importing the module and retrieving its C API pointers; client modules only have to call this macro before accessing the C API.

The exporting module is a modification of the `spam` module from section *A Simple Example*. The function `spam.system()` does not call the C library function `system()` directly, but a function `PySpam_System()`, which would of course do something more complicated in reality (such as adding "spam" to every command). This function `PySpam_System()` is also exported to other extension modules.

The function `PySpam_System()` is a plain C function, declared `static` like everything else:

```
static int
PySpam_System(const char *command)
{
    return system(command);
}
```

The function `spam_system()` is modified in a trivial way:

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = PySpam_System(command);
    return Py_BuildValue("i", sts);
}
```

In the beginning of the module, right after the line

```
#include "Python.h"
```

two more lines must be added:

```
#define SPAM_MODULE
#include "spammodule.h"
```

The `#define` is used to tell the header file that it is being included in the exporting module, not a client module. Finally, the module's initialization function must take care of initializing the C API pointer array:

```
PyMODINIT_FUNC
initspam(void)
{
    PyObject *m;
    static void *PySpam_API[PySpam_API_pointers];
    PyObject *c_api_object;

    m = Py_InitModule("spam", SpamMethods);
    if (m == NULL)
        return;

    /* Initialize the C API pointer array */
    PySpam_API[PySpam_System_NUM] = (void *)PySpam_System;

    /* Create a Capsule containing the API pointer array's address */
    c_api_object = PyCapsule_New((void *)PySpam_API, "spam._C_API", NULL);

    if (c_api_object != NULL)
        PyModule_AddObject(m, "_C_API", c_api_object);
}
```

Note that `PySpam_API` is declared `static`; otherwise the pointer array would disappear when `initspam()` terminates!

The bulk of the work is in the header file `spammodule.h`, which looks like this:

```
#ifndef Py_SPAMMODULE_H
#define Py_SPAMMODULE_H
#ifdef __cplusplus
extern "C" {
#endif

/* Header file for spammodule */

/* C API functions */
#define PySpam_System_NUM 0
#define PySpam_System_RETURN int
#define PySpam_System_PROTO (const char *command)

/* Total number of C API pointers */
#define PySpam_API_pointers 1

#ifdef SPAM_MODULE
/* This section is used when compiling spammodule.c */

static PySpam_System_RETURN PySpam_System PySpam_System_PROTO;

#else
```

```
/* This section is used in modules that use spammodule's API */

static void **PySpam_API;

#define PySpam_System \
    (*(PySpam_System_RETURN (*)PySpam_System_PROTO) PySpam_API[PySpam_System_NUM])

/* Return -1 on error, 0 on success.
 * PyCapsule_Import will set an exception if there's an error.
 */
static int
import_spam(void)
{
    PySpam_API = (void **)PyCapsule_Import("spam._C_API", 0);
    return (PySpam_API != NULL) ? 0 : -1;
}

#endif

#ifdef __cplusplus
}
#endif

#endif /* !defined(Py_SPAMMODULE_H) */
```

All that a client module must do in order to have access to the function `PySpam_System()` is to call the function (or rather macro) `import_spam()` in its initialization function:

```
PyMODINIT_FUNC
initclient(void)
{
    PyObject *m;

    m = Py_InitModule("client", ClientMethods);
    if (m == NULL)
        return;
    if (import_spam() < 0)
        return;
    /* additional initialization can happen here */
}
```

The main disadvantage of this approach is that the file `spammodule.h` is rather complicated. However, the basic structure is the same for each function that is exported, so it has to be learned only once.

Finally it should be mentioned that Capsules offer additional functionality, which is especially useful for memory allocation and deallocation of the pointer stored in a Capsule. The details are described in the Python/C API Reference Manual in the section *capsules* and in the implementation of Capsules (files `Include/pycapsule.h` and `Objects/pycapsule.c` in the Python source code distribution).

# DEFINING NEW TYPES

As mentioned in the last chapter, Python allows the writer of an extension module to define new types that can be manipulated from Python code, much like strings and lists in core Python.

This is not hard; the code for all extension types follows a pattern, but there are some details that you need to understand before you can get started.

---

**Note:** The way new types are defined changed dramatically (and for the better) in Python 2.2. This document documents how to define new types for Python 2.2 and later. If you need to support older versions of Python, you will need to refer to [older versions of this documentation](#).

---

## 2.1 The Basics

The Python runtime sees all Python objects as variables of type `PyObject*`. A `PyObject` is not a very magnificent object - it just contains the refcount and a pointer to the object's "type object". This is where the action is; the type object determines which (C) functions get called when, for instance, an attribute gets looked up on an object or it is multiplied by another object. These C functions are called "type methods".

So, if you want to define a new object type, you need to create a new type object.

This sort of thing can only be explained by example, so here's a minimal, but complete, module that defines a new type:

```
#include <Python.h>

typedef struct {
    PyObject_HEAD
    /* Type-specific fields go here. */
} noddy_NoddyObject;

static PyTypeObject noddy_NoddyType = {
    PyObject_HEAD_INIT(NULL)
    0,                          /*ob_size*/
    "noddy.Noddy",              /*tp_name*/
    sizeof(noddy_NoddyObject),  /*tp_basicsize*/
    0,                          /*tp_itemsize*/
    0,                          /*tp_dealloc*/
    0,                          /*tp_print*/
    0,                          /*tp_getattr*/
    0,                          /*tp_setattr*/
```

```

    0,          /*tp_compare*/
    0,          /*tp_repr*/
    0,          /*tp_as_number*/
    0,          /*tp_as_sequence*/
    0,          /*tp_as_mapping*/
    0,          /*tp_hash */
    0,          /*tp_call*/
    0,          /*tp_str*/
    0,          /*tp_getattro*/
    0,          /*tp_setattro*/
    0,          /*tp_as_buffer*/
    Py_TPFLAGS_DEFAULT, /*tp_flags*/
    "Noddy objects",    /* tp_doc */
};

static PyMethodDef noddy_methods[] = {
    {NULL} /* Sentinel */
};

#ifdef PyMODINIT_FUNC      /* declarations for DLL import/export */
#define PyMODINIT_FUNC void
#endif
PyMODINIT_FUNC
initnoddy(void)
{
    PyObject* m;

    noddy_NoddyType.tp_new = PyType_GenericNew;
    if (PyType_Ready(&noddy_NoddyType) < 0)
        return;

    m = Py_InitModule3("noddy", noddy_methods,
        "Example module that creates an extension type.");

    Py_INCREF(&noddy_NoddyType);
    PyModule_AddObject(m, "Noddy", (PyObject *)&noddy_NoddyType);
}

```

Now that's quite a bit to take in at once, but hopefully bits will seem familiar from the last chapter.

The first bit that will be new is:

```

typedef struct {
    PyObject_HEAD
} noddy_NoddyObject;

```

This is what a Noddy object will contain—in this case, nothing more than every Python object contains, namely a refcount and a pointer to a type object. These are the fields the `PyObject_HEAD` macro brings in. The reason for the macro is to standardize the layout and to enable special debugging fields in debug builds. Note that there is no semicolon after the `PyObject_HEAD` macro; one is included in the macro definition. Be wary of adding one by accident; it's easy to do from habit, and your compiler might not complain, but someone else's probably will! (On Windows, MSVC is known to call this an error and refuse to compile the code.)

For contrast, let's take a look at the corresponding definition for standard Python integers:

```

typedef struct {
    PyObject_HEAD

```

```

        long ob_ival;
    } PyIntObject;

```

Moving on, we come to the crunch — the type object.

```

static PyObject noddy_NoddyType = {
    PyObject_HEAD_INIT(NULL)
    0, /*ob_size*/
    "noddy.Noddy", /*tp_name*/
    sizeof(noddy_NoddyObject), /*tp_basicsize*/
    0, /*tp_itemsize*/
    0, /*tp_dealloc*/
    0, /*tp_print*/
    0, /*tp_getattr*/
    0, /*tp_setattr*/
    0, /*tp_compare*/
    0, /*tp_repr*/
    0, /*tp_as_number*/
    0, /*tp_as_sequence*/
    0, /*tp_as_mapping*/
    0, /*tp_hash */
    0, /*tp_call*/
    0, /*tp_str*/
    0, /*tp_getattro*/
    0, /*tp_setattro*/
    0, /*tp_as_buffer*/
    Py_TPFLAGS_DEFAULT, /*tp_flags*/
    "Noddy objects", /* tp_doc */
};

```

Now if you go and look up the definition of `PyObject` in `object.h` you'll see that it has many more fields than the definition above. The remaining fields will be filled with zeros by the C compiler, and it's common practice to not specify them explicitly unless you need them.

This is so important that we're going to pick the top of it apart still further:

```
PyObject_HEAD_INIT(NULL)
```

This line is a bit of a wart; what we'd like to write is:

```
PyObject_HEAD_INIT(&PyType_Type)
```

as the type of a type object is "type", but this isn't strictly conforming C and some compilers complain. Fortunately, this member will be filled in for us by `PyType_Ready()`.

```
0, /* ob_size */
```

The `ob_size` field of the header is not used; its presence in the type structure is a historical artifact that is maintained for binary compatibility with extension modules compiled for older versions of Python. Always set this field to zero.

```
"noddy.Noddy", /* tp_name */
```

The name of our type. This will appear in the default textual representation of our objects and in some error messages, for example:

```

>>> "" + noddy.new_noddy()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: cannot add type "noddy.Noddy" to string

```

Note that the name is a dotted name that includes both the module name and the name of the type within the module. The module in this case is `noddy` and the type is `Noddy`, so we set the type name to `noddy.Noddy`.

```
sizeof(noddy_NoddyObject), /* tp_basicsize */
```

This is so that Python knows how much memory to allocate when you call `PyObject_New()`.

---

**Note:** If you want your type to be subclassable from Python, and your type has the same `tp_basicsize` as its base type, you may have problems with multiple inheritance. A Python subclass of your type will have to list your type first in its `__bases__`, or else it will not be able to call your type's `__new__()` method without getting an error. You can avoid this problem by ensuring that your type has a larger value for `tp_basicsize` than its base type does. Most of the time, this will be true anyway, because either your base type will be `object`, or else you will be adding data members to your base type, and therefore increasing its size.

---

```
0, /* tp_itemsize */
```

This has to do with variable length objects like lists and strings. Ignore this for now.

Skipping a number of type methods that we don't provide, we set the class flags to `Py_TPFLAGS_DEFAULT`.

```
Py_TPFLAGS_DEFAULT, /*tp_flags*/
```

All types should include this constant in their flags. It enables all of the members defined by the current version of Python.

We provide a doc string for the type in `tp_doc`.

```
"Noddy objects", /* tp_doc */
```

Now we get into the type methods, the things that make your objects different from the others. We aren't going to implement any of these in this version of the module. We'll expand this example later to have more interesting behavior.

For now, all we want to be able to do is to create new `Noddy` objects. To enable object creation, we have to provide a `tp_new` implementation. In this case, we can just use the default implementation provided by the API function `PyType_GenericNew()`. We'd like to just assign this to the `tp_new` slot, but we can't, for portability sake. On some platforms or compilers, we can't statically initialize a structure member with a function defined in another C module, so, instead, we'll assign the `tp_new` slot in the module initialization function just before calling `PyType_Ready()`:

```
noddy_NoddyType.tp_new = PyType_GenericNew;
if (PyType_Ready(&noddy_NoddyType) < 0)
    return;
```

All the other type methods are `NULL`, so we'll go over them later — that's for a later section!

Everything else in the file should be familiar, except for some code in `initnoddy()`:

```
if (PyType_Ready(&noddy_NoddyType) < 0)
    return;
```

This initializes the `Noddy` type, filling in a number of members, including `ob_type` that we initially set to `NULL`.

```
PyModule_AddObject(m, "Noddy", (PyObject *)&noddy_NoddyType);
```

This adds the type to the module dictionary. This allows us to create `Noddy` instances by calling the `Noddy` class:

```
>>> import noddy
>>> mynoddy = noddy.Noddy()
```

That's it! All that remains is to build it; put the above code in a file called `noddy.c` and

```

from distutils.core import setup, Extension
setup(name="noddy", version="1.0",
      ext_modules=[Extension("noddy", ["noddy.c"])]
    )
    
```

in a file called `setup.py`; then typing

```
$ python setup.py build
```

at a shell should produce a file `noddy.so` in a subdirectory; move to that directory and fire up Python — you should be able to import `noddy` and play around with Noddy objects.

That wasn't so hard, was it?

Of course, the current Noddy type is pretty uninteresting. It has no data and doesn't do anything. It can't even be subclassed.

## 2.1.1 Adding data and methods to the Basic example

Let's expand the basic example to add some data and methods. Let's also make the type usable as a base class. We'll create a new module, `noddy2` that adds these capabilities:

```

#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last; /* last name */
    int number;
} Noddy;

static void
Noddy_dealloc(Noddy* self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    self->ob_type->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyString_FromString("");
        if (self->first == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->last = PyString_FromString("");
        if (self->last == NULL)
        {
    
```

```

        Py_DECREF(self);
        return NULL;
    }

    self->number = 0;
}

return (PyObject *)self;
}

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number", NULL};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_XDECREF(tmp);
    }

    return 0;
}

static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(Noddy, last), 0,
     "last name"},
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
{
    static PyObject *format = NULL;

```

```

PyObject *args, *result;

if (format == NULL) {
    format = PyString_FromString("%s %s");
    if (format == NULL)
        return NULL;
}

if (self->first == NULL) {
    PyErr_SetString(PyExc_AttributeError, "first");
    return NULL;
}

if (self->last == NULL) {
    PyErr_SetString(PyExc_AttributeError, "last");
    return NULL;
}

args = Py_BuildValue("OO", self->first, self->last);
if (args == NULL)
    return NULL;

result = PyString_Format(format, args);
Py_DECREF(args);

return result;
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL} /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyObject_HEAD_INIT(NULL)
    0, /*ob_size*/
    "noddy.Noddy", /*tp_name*/
    sizeof(Noddy), /*tp_basicsize*/
    0, /*tp_itemsize*/
    (destructor)Noddy_dealloc, /*tp_dealloc*/
    0, /*tp_print*/
    0, /*tp_getattr*/
    0, /*tp_setattr*/
    0, /*tp_compare*/
    0, /*tp_repr*/
    0, /*tp_as_number*/
    0, /*tp_as_sequence*/
    0, /*tp_as_mapping*/
    0, /*tp_hash */
    0, /*tp_call*/
    0, /*tp_str*/
    0, /*tp_getattro*/

```

```

    0,                /*tp_setattro*/
    0,                /*tp_as_buffer*/
    Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE, /*tp_flags*/
    "Noddy objects",  /* tp_doc */
    0,                /* tp_traverse */
    0,                /* tp_clear */
    0,                /* tp_richcompare */
    0,                /* tp_weaklistoffset */
    0,                /* tp_iter */
    0,                /* tp_iternext */
    Noddy_methods,   /* tp_methods */
    Noddy_members,   /* tp_members */
    0,                /* tp_getset */
    0,                /* tp_base */
    0,                /* tp_dict */
    0,                /* tp_descr_get */
    0,                /* tp_descr_set */
    0,                /* tp_dictoffset */
    (initproc)Noddy_init, /* tp_init */
    0,                /* tp_alloc */
    Noddy_new,        /* tp_new */
};

static PyMethodDef module_methods[] = {
    {NULL} /* Sentinel */
};

#ifdef PyMODINIT_FUNC      /* declarations for DLL import/export */
#define PyMODINIT_FUNC void
#endif
PyMODINIT_FUNC
initnoddy2(void)
{
    PyObject* m;

    if (PyType_Ready(&NoddyType) < 0)
        return;

    m = Py_InitModule3("noddy2", module_methods,
        "Example module that creates an extension type.");

    if (m == NULL)
        return;

    Py_INCREF(&NoddyType);
    PyModule_AddObject(m, "Noddy", (PyObject *)&NoddyType);
}

```

This version of the module has a number of changes.

We've added an extra include:

```
#include <structmember.h>
```

This include provides declarations that we use to handle attributes, as described a bit later.

The name of the Noddy object structure has been shortened to Noddy. The type object name has been shortened to NoddyType.

The Noddy type now has three data attributes, *first*, *last*, and *number*. The *first* and *last* variables are Python strings containing first and last names. The *number* attribute is an integer.

The object structure is updated accordingly:

```
typedef struct {
    PyObject_HEAD
    PyObject *first;
    PyObject *last;
    int number;
} Noddy;
```

Because we now have data to manage, we have to be more careful about object allocation and deallocation. At a minimum, we need a deallocation method:

```
static void
Noddy_dealloc(Noddy* self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    self->ob_type->tp_free((PyObject*)self);
}
```

which is assigned to the `tp_dealloc` member:

```
(destructor)Noddy_dealloc, /*tp_dealloc*/
```

This method decrements the reference counts of the two Python attributes. We use `Py_XDECREF()` here because the *first* and *last* members could be *NULL*. It then calls the `tp_free` member of the object's type to free the object's memory. Note that the object's type might not be `NoddyType`, because the object may be an instance of a subclass.

We want to make sure that the first and last names are initialized to empty strings, so we provide a new method:

```
static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyString_FromString("");
        if (self->first == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->last = PyString_FromString("");
        if (self->last == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->number = 0;
    }
}
```

```

    }

    return (PyObject *)self;
}

```

and install it in the `tp_new` member:

```
Noddy_new,          /* tp_new */
```

The new member is responsible for creating (as opposed to initializing) objects of the type. It is exposed in Python as the `__new__()` method. See the paper titled “Unifying types and classes in Python” for a detailed discussion of the `__new__()` method. One reason to implement a new method is to assure the initial values of instance variables. In this case, we use the new method to make sure that the initial values of the members `first` and `last` are not `NULL`. If we didn’t care whether the initial values were `NULL`, we could have used `PyType_GenericNew()` as our new method, as we did before. `PyType_GenericNew()` initializes all of the instance variable members to `NULL`.

The new method is a static method that is passed the type being instantiated and any arguments passed when the type was called, and that returns the new object created. New methods always accept positional and keyword arguments, but they often ignore the arguments, leaving the argument handling to initializer methods. Note that if the type supports subclassing, the type passed may not be the type being defined. The new method calls the `tp_alloc` slot to allocate memory. We don’t fill the `tp_alloc` slot ourselves. Rather `PyType_Ready()` fills it for us by inheriting it from our base class, which is `object` by default. Most types use the default allocation.

---

**Note:** If you are creating a co-operative `tp_new` (one that calls a base type’s `tp_new` or `__new__()`), you must *not* try to determine what method to call using method resolution order at runtime. Always statically determine what type you are going to call, and call its `tp_new` directly, or via `type->tp_base->tp_new`. If you do not do this, Python subclasses of your type that also inherit from other Python-defined classes may not work correctly. (Specifically, you may not be able to create instances of such subclasses without getting a `TypeError`.)

---

We provide an initialization function:

```

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number", NULL};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", kwlist,
                                     &first, &last,
                                     &self->number))

        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_XDECREF(tmp);
    }
}

```

```

        return 0;
    }

```

by filling the `tp_init` slot.

```
(initproc)Noddy_init,          /* tp_init */
```

The `tp_init` slot is exposed in Python as the `__init__()` method. It is used to initialize an object after it's created. Unlike the new method, we can't guarantee that the initializer is called. The initializer isn't called when unpickling objects and it can be overridden. Our initializer accepts arguments to provide initial values for our instance. Initializers always accept positional and keyword arguments.

Initializers can be called multiple times. Anyone can call the `__init__()` method on our objects. For this reason, we have to be extra careful when assigning the new values. We might be tempted, for example to assign the `first` member like this:

```

if (first) {
    Py_XDECREF(self->first);
    Py_INCREF(first);
    self->first = first;
}

```

But this would be risky. Our type doesn't restrict the type of the `first` member, so it could be any kind of object. It could have a destructor that causes code to be executed that tries to access the `first` member. To be paranoid and protect ourselves against this possibility, we almost always reassign members before decrementing their reference counts. When don't we have to do this?

- when we absolutely know that the reference count is greater than 1
- when we know that deallocation of the object <sup>1</sup> will not cause any calls back into our type's code
- when decrementing a reference count in a `tp_dealloc` handler when garbage-collections is not supported <sup>2</sup>

We want to expose our instance variables as attributes. There are a number of ways to do that. The simplest way is to define member definitions:

```

static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(Noddy, last), 0,
     "last name"},
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};

```

and put the definitions in the `tp_members` slot:

```
Noddy_members,          /* tp_members */
```

Each member definition has a member name, type, offset, access flags and documentation string. See the *Generic Attribute Management* section below for details.

A disadvantage of this approach is that it doesn't provide a way to restrict the types of objects that can be assigned to the Python attributes. We expect the first and last names to be strings, but any Python objects can be assigned. Further, the attributes can be deleted, setting the C pointers to `NULL`. Even though we can make sure the members are initialized to non-`NULL` values, the members can be set to `NULL` if the attributes are deleted.

<sup>1</sup> This is true when we know that the object is a basic type, like a string or a float.

<sup>2</sup> We relied on this in the `tp_dealloc` handler in this example, because our type doesn't support garbage collection. Even if a type supports garbage collection, there are calls that can be made to "untrack" the object from garbage collection, however, these calls are advanced and not covered here.

We define a single method, `name()`, that outputs the objects name as the concatenation of the first and last names.

```
static PyObject *
Noddy_name(Noddy* self)
{
    static PyObject *format = NULL;
    PyObject *args, *result;

    if (format == NULL) {
        format = PyString_FromString("%s %s");
        if (format == NULL)
            return NULL;
    }

    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first");
        return NULL;
    }

    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last");
        return NULL;
    }

    args = Py_BuildValue("OO", self->first, self->last);
    if (args == NULL)
        return NULL;

    result = PyString_Format(format, args);
    Py_DECREF(args);

    return result;
}
```

The method is implemented as a C function that takes a `Noddy` (or `Noddy` subclass) instance as the first argument. Methods always take an instance as the first argument. Methods often take positional and keyword arguments as well, but in this case we don't take any and don't need to accept a positional argument tuple or keyword argument dictionary. This method is equivalent to the Python method:

```
def name(self):
    return "%s %s" % (self.first, self.last)
```

Note that we have to check for the possibility that our `first` and `last` members are `NULL`. This is because they can be deleted, in which case they are set to `NULL`. It would be better to prevent deletion of these attributes and to restrict the attribute values to be strings. We'll see how to do that in the next section.

Now that we've defined the method, we need to create an array of method definitions:

```
static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last name"},
    },
    {NULL} /* Sentinel */
};
```

and assign them to the `tp_methods` slot:

```
Noddy_methods, /* tp_methods */
```

Note that we used the `METH_NOARGS` flag to indicate that the method is passed no arguments.

Finally, we'll make our type usable as a base class. We've written our methods carefully so far so that they don't make any assumptions about the type of the object being created or used, so all we need to do is to add the `Py_TPFLAGS_BASETYPE` to our class flag definition:

```
Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE, /*tp_flags*/
```

We rename `initnoddy()` to `initnoddy2()` and update the module name passed to `Py_InitModule3()`.

Finally, we update our `setup.py` file to build the new module:

```
from distutils.core import setup, Extension
setup(name="noddy", version="1.0",
      ext_modules=[
          Extension("noddy", ["noddy.c"]),
          Extension("noddy2", ["noddy2.c"]),
      ])
```

## 2.1.2 Providing finer control over data attributes

In this section, we'll provide finer control over how the `first` and `last` attributes are set in the Noddy example. In the previous version of our module, the instance variables `first` and `last` could be set to non-string values or even deleted. We want to make sure that these attributes always contain strings.

```
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first;
    PyObject *last;
    int number;
} Noddy;

static void
Noddy_dealloc(Noddy* self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    self->ob_type->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyString_FromString("");
        if (self->first == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }
    }
}
```

```

        self->last = PyString_FromString("");
        if (self->last == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->number = 0;
    }

    return (PyObject *)self;
}

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number", NULL};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|SSi", kwlist,
                                     &first, &last,
                                     &self->number))

        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }

    return 0;
}

static PyMemberDef Noddy_members[] = {
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_getfirst(Noddy *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

```

```

}

static int
Noddy_setfirst(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the first attribute");
        return -1;
    }

    if (!PyString_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
            "The first attribute value must be a string");
        return -1;
    }

    Py_DECREF(self->first);
    Py_INCREF(value);
    self->first = value;

    return 0;
}

static PyObject *
Noddy_getlast(Noddy *self, void *closure)
{
    Py_INCREF(self->last);
    return self->last;
}

static int
Noddy_setlast(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the last attribute");
        return -1;
    }

    if (!PyString_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
            "The last attribute value must be a string");
        return -1;
    }

    Py_DECREF(self->last);
    Py_INCREF(value);
    self->last = value;

    return 0;
}

static PyGetSetDef Noddy_getseters[] = {
    {"first",
     (getter)Noddy_getfirst, (setter)Noddy_setfirst,

```

```

        "first name",
        NULL},
    {"last",
     (getter)Noddy_getlast, (setter)Noddy_setlast,
     "last name",
     NULL},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
{
    static PyObject *format = NULL;
    PyObject *args, *result;

    if (format == NULL) {
        format = PyString_FromString("%s %s");
        if (format == NULL)
            return NULL;
    }

    args = Py_BuildValue("OO", self->first, self->last);
    if (args == NULL)
        return NULL;

    result = PyString_Format(format, args);
    Py_DECREF(args);

    return result;
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last name"},
    {NULL} /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyObject_HEAD_INIT(NULL)
    0, /*ob_size*/
    "noddy.Noddy", /*tp_name*/
    sizeof(Noddy), /*tp_basicsize*/
    0, /*tp_itemsize*/
    (destructor)Noddy_dealloc, /*tp_dealloc*/
    0, /*tp_print*/
    0, /*tp_getattr*/
    0, /*tp_setattr*/
    0, /*tp_compare*/
    0, /*tp_repr*/
    0, /*tp_as_number*/
    0, /*tp_as_sequence*/
    0, /*tp_as_mapping*/
    0, /*tp_hash */

```

```

    0,          /*tp_call*/
    0,          /*tp_str*/
    0,          /*tp_getattro*/
    0,          /*tp_setattro*/
    0,          /*tp_as_buffer*/
    Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE, /*tp_flags*/
    "Noddy objects", /* tp_doc */
    0,          /* tp_traverse */
    0,          /* tp_clear */
    0,          /* tp_richcompare */
    0,          /* tp_weaklistoffset */
    0,          /* tp_iter */
    0,          /* tp_iternext */
    Noddy_methods, /* tp_methods */
    Noddy_members, /* tp_members */
    Noddy_getsetters, /* tp_getset */
    0,          /* tp_base */
    0,          /* tp_dict */
    0,          /* tp_descr_get */
    0,          /* tp_descr_set */
    0,          /* tp_dictoffset */
    (initproc)Noddy_init, /* tp_init */
    0,          /* tp_alloc */
    Noddy_new, /* tp_new */
};

static PyMethodDef module_methods[] = {
    {NULL} /* Sentinel */
};

#ifdef PyMODINIT_FUNC /* declarations for DLL import/export */
#define PyMODINIT_FUNC void
#endif
PyMODINIT_FUNC
initnoddy3(void)
{
    PyObject* m;

    if (PyType_Ready(&NoddyType) < 0)
        return;

    m = Py_InitModule3("noddy3", module_methods,
        "Example module that creates an extension type.");

    if (m == NULL)
        return;

    Py_INCREF(&NoddyType);
    PyModule_AddObject(m, "Noddy", (PyObject *)&NoddyType);
}

```

To provide greater control, over the first and last attributes, we'll use custom getter and setter functions. Here are the functions for getting and setting the first attribute:

```

Noddy_getfirst(Noddy *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

static int
Noddy_setfirst(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the first attribute");
        return -1;
    }

    if (!PyString_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
            "The first attribute value must be a string");
        return -1;
    }

    Py_DECREF(self->first);
    Py_INCREF(value);
    self->first = value;

    return 0;
}

```

The getter function is passed a `Noddy` object and a “closure”, which is void pointer. In this case, the closure is ignored. (The closure supports an advanced usage in which definition data is passed to the getter and setter. This could, for example, be used to allow a single set of getter and setter functions that decide the attribute to get or set based on data in the closure.)

The setter function is passed the `Noddy` object, the new value, and the closure. The new value may be `NULL`, in which case the attribute is being deleted. In our setter, we raise an error if the attribute is deleted or if the attribute value is not a string.

We create an array of `PyGetSetDef` structures:

```

static PyGetSetDef Noddy_getsetters[] = {
    {"first",
     (getter)Noddy_getfirst, (setter)Noddy_setfirst,
     "first name",
     NULL},
    {"last",
     (getter)Noddy_getlast, (setter)Noddy_setlast,
     "last name",
     NULL},
    {NULL} /* Sentinel */
};

```

and register it in the `tp_getset` slot:

```

Noddy_getsetters, /* tp_getset */

```

to register our attribute getters and setters.

The last item in a `PyGetSetDef` structure is the closure mentioned above. In this case, we aren’t using the closure, so we just pass `NULL`.

We also remove the member definitions for these attributes:

```
static PyMemberDef Noddy_members[] = {
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};
```

We also need to update the `tp_init` handler to only allow strings<sup>3</sup> to be passed:

```
static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number", NULL};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|SSi", kwlist,
                                       &first, &last,
                                       &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }

    return 0;
}
```

With these changes, we can assure that the `first` and `last` members are never `NULL` so we can remove checks for `NULL` values in almost all cases. This means that most of the `Py_XDECREF()` calls can be converted to `Py_DECREF()` calls. The only place we can't change these calls is in the deallocator, where there is the possibility that the initialization of these members failed in the constructor.

We also rename the module initialization function and module name in the initialization function, as we did before, and we add an extra definition to the `setup.py` file.

### 2.1.3 Supporting cyclic garbage collection

Python has a cyclic-garbage collector that can identify unneeded objects even when their reference counts are not zero. This can happen when objects are involved in cycles. For example, consider:

<sup>3</sup> We now know that the `first` and `last` members are strings, so perhaps we could be less careful about decrementing their reference counts, however, we accept instances of string subclasses. Even though deallocating normal strings won't call back into our objects, we can't guarantee that deallocating an instance of a string subclass won't call back into our objects.

```
>>> l = []
>>> l.append(l)
>>> del l
```

In this example, we create a list that contains itself. When we delete it, it still has a reference from itself. Its reference count doesn't drop to zero. Fortunately, Python's cyclic-garbage collector will eventually figure out that the list is garbage and free it.

In the second version of the Noddy example, we allowed any kind of object to be stored in the `first` or `last` attributes.<sup>4</sup> This means that Noddy objects can participate in cycles:

```
>>> import noddy2
>>> n = noddy2.Noddy()
>>> l = [n]
>>> n.first = l
```

This is pretty silly, but it gives us an excuse to add support for the cyclic-garbage collector to the Noddy example. To support cyclic garbage collection, types need to fill two slots and set a class flag that enables these slots:

```
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first;
    PyObject *last;
    int number;
} Noddy;

static int
Noddy_traverse(Noddy *self, visitproc visit, void *arg)
{
    int vret;

    if (self->first) {
        vret = visit(self->first, arg);
        if (vret != 0)
            return vret;
    }
    if (self->last) {
        vret = visit(self->last, arg);
        if (vret != 0)
            return vret;
    }

    return 0;
}

static int
Noddy_clear(Noddy *self)
{
    PyObject *tmp;

    tmp = self->first;
```

---

<sup>4</sup> Even in the third version, we aren't guaranteed to avoid cycles. Instances of string subclasses are allowed and string subclasses could allow cycles even if normal strings don't.

```

    self->first = NULL;
    Py_XDECREF(tmp);

    tmp = self->last;
    self->last = NULL;
    Py_XDECREF(tmp);

    return 0;
}

static void
Noddy_dealloc(Noddy* self)
{
    Noddy_clear(self);
    self->ob_type->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyString_FromString("");
        if (self->first == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->last = PyString_FromString("");
        if (self->last == NULL)
        {
            Py_DECREF(self);
            return NULL;
        }

        self->number = 0;
    }

    return (PyObject *)self;
}

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number", NULL};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", kwlist,
                                       &first, &last,
                                       &self->number))

```

```

        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_XDECREF(tmp);
    }

    return 0;
}

static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(Noddy, last), 0,
     "last name"},
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
{
    static PyObject *format = NULL;
    PyObject *args, *result;

    if (format == NULL) {
        format = PyString_FromString("%s %s");
        if (format == NULL)
            return NULL;
    }

    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first");
        return NULL;
    }

    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last");
        return NULL;
    }

    args = Py_BuildValue("OO", self->first, self->last);
    if (args == NULL)

```

```

        return NULL;

    result = PyString_Format(format, args);
    Py_DECREF(args);

    return result;
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL} /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyObject_HEAD_INIT(NULL)
    0, /*ob_size*/
    "noddy.Noddy", /*tp_name*/
    sizeof(Noddy), /*tp_basicsize*/
    0, /*tp_itemsize*/
    (destructor)Noddy_dealloc, /*tp_dealloc*/
    0, /*tp_print*/
    0, /*tp_getattr*/
    0, /*tp_setattr*/
    0, /*tp_compare*/
    0, /*tp_repr*/
    0, /*tp_as_number*/
    0, /*tp_as_sequence*/
    0, /*tp_as_mapping*/
    0, /*tp_hash */
    0, /*tp_call*/
    0, /*tp_str*/
    0, /*tp_getattro*/
    0, /*tp_setattro*/
    0, /*tp_as_buffer*/
    Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC, /*tp_flags*/
    "Noddy objects", /* tp_doc */
    (traverseproc)Noddy_traverse, /* tp_traverse */
    (inquiry)Noddy_clear, /* tp_clear */
    0, /* tp_richcompare */
    0, /* tp_weaklistoffset */
    0, /* tp_iter */
    0, /* tp_iternext */
    Noddy_methods, /* tp_methods */
    Noddy_members, /* tp_members */
    0, /* tp_getset */
    0, /* tp_base */
    0, /* tp_dict */
    0, /* tp_descr_get */
    0, /* tp_descr_set */
    0, /* tp_dictoffset */
    (initproc)Noddy_init, /* tp_init */
    0, /* tp_alloc */
};

```

```

        Noddy_new,                /* tp_new */
    };

    static PyMethodDef module_methods[] = {
        {NULL} /* Sentinel */
    };

    #ifndef PyMODINIT_FUNC        /* declarations for DLL import/export */
    #define PyMODINIT_FUNC void
    #endif
    PyMODINIT_FUNC
    initsnoddy4(void)
    {
        PyObject* m;

        if (PyType_Ready(&NoddyType) < 0)
            return;

        m = Py_InitModule3("noddy4", module_methods,
            "Example module that creates an extension type.");

        if (m == NULL)
            return;

        Py_INCREF(&NoddyType);
        PyModule_AddObject(m, "Noddy", (PyObject *)&NoddyType);
    }

```

The traversal method provides access to subobjects that could participate in cycles:

```

    static int
    Noddy_traverse(Noddy *self, visitproc visit, void *arg)
    {
        int vret;

        if (self->first) {
            vret = visit(self->first, arg);
            if (vret != 0)
                return vret;
        }
        if (self->last) {
            vret = visit(self->last, arg);
            if (vret != 0)
                return vret;
        }

        return 0;
    }

```

For each subobject that can participate in cycles, we need to call the `visit()` function, which is passed to the traversal method. The `visit()` function takes as arguments the subobject and the extra argument `arg` passed to the traversal method. It returns an integer value that must be returned if it is non-zero.

Python 2.4 and higher provide a `Py_VISIT()` macro that automates calling visit functions. With `Py_VISIT()`, `Noddy_traverse()` can be simplified:

```

static int
Noddy_traverse(Noddy *self, visitproc visit, void *arg)
{
    Py_VISIT(self->first);
    Py_VISIT(self->last);
    return 0;
}
    
```

---

**Note:** Note that the `tp_traverse` implementation must name its arguments exactly *visit* and *arg* in order to use `Py_VISIT()`. This is to encourage uniformity across these boring implementations.

---

We also need to provide a method for clearing any subobjects that can participate in cycles. We implement the method and reimplement the deallocator to use it:

```

static int
Noddy_clear(Noddy *self)
{
    PyObject *tmp;

    tmp = self->first;
    self->first = NULL;
    Py_XDECREF(tmp);

    tmp = self->last;
    self->last = NULL;
    Py_XDECREF(tmp);

    return 0;
}

static void
Noddy_dealloc(Noddy* self)
{
    Noddy_clear(self);
    self->ob_type->tp_free((PyObject*) self);
}
    
```

Notice the use of a temporary variable in `Noddy_clear()`. We use the temporary variable so that we can set each member to `NULL` before decrementing its reference count. We do this because, as was discussed earlier, if the reference count drops to zero, we might cause code to run that calls back into the object. In addition, because we now support garbage collection, we also have to worry about code being run that triggers garbage collection. If garbage collection is run, our `tp_traverse` handler could get called. We can't take a chance of having `Noddy_traverse()` called when a member's reference count has dropped to zero and its value hasn't been set to `NULL`.

Python 2.4 and higher provide a `Py_CLEAR()` that automates the careful decrementing of reference counts. With `Py_CLEAR()`, the `Noddy_clear()` function can be simplified:

```

static int
Noddy_clear(Noddy *self)
{
    Py_CLEAR(self->first);
    Py_CLEAR(self->last);
    return 0;
}
    
```

Finally, we add the `Py_TPFLAGS_HAVE_GC` flag to the class flags:

```
Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC, /*tp_flags*/
```

That's pretty much it. If we had written custom `tp_alloc` or `tp_free` slots, we'd need to modify them for cyclic-garbage collection. Most extensions will use the versions automatically provided.

## 2.1.4 Subclassing other types

It is possible to create new extension types that are derived from existing types. It is easiest to inherit from the built-in types, since an extension can easily use the `PyObject` it needs. It can be difficult to share these `PyObject` structures between extension modules.

In this example we will create a `Shoddy` type that inherits from the built-in `list` type. The new type will be completely compatible with regular lists, but will have an additional `increment()` method that increases an internal counter.

```
>>> import shoddy
>>> s = shoddy.Shoddy(range(3))
>>> s.extend(s)
>>> print len(s)
6
>>> print s.increment()
1
>>> print s.increment()
2
```

```
#include <Python.h>
```

```
typedef struct {
    PyObject list;
    int state;
} Shoddy;
```

```
static PyObject *
Shoddy_increment(Shoddy *self, PyObject *unused)
{
    self->state++;
    return PyInt_FromLong(self->state);
}
```

```
static PyMethodDef Shoddy_methods[] = {
    {"increment", (PyCFunction)Shoddy_increment, METH_NOARGS,
     PyDoc_STR("increment state counter")},
    {NULL, NULL},
};
```

```
static int
Shoddy_init(Shoddy *self, PyObject *args, PyObject *kwds)
{
    if (PyList_Type.tp_init((PyObject *)self, args, kwds) < 0)
        return -1;
    self->state = 0;
    return 0;
}
```

```

static PyObject ShoddyType = {
    PyObject_HEAD_INIT(NULL)
    0, /* ob_size */
    "shoddy.Shoddy", /* tp_name */
    sizeof(Shoddy), /* tp_basicsize */
    0, /* tp_itemsize */
    0, /* tp_dealloc */
    0, /* tp_print */
    0, /* tp_getattr */
    0, /* tp_setattr */
    0, /* tp_compare */
    0, /* tp_repr */
    0, /* tp_as_number */
    0, /* tp_as_sequence */
    0, /* tp_as_mapping */
    0, /* tp_hash */
    0, /* tp_call */
    0, /* tp_str */
    0, /* tp_getattro */
    0, /* tp_setattro */
    0, /* tp_as_buffer */
    Py_TPFLAGS_DEFAULT |
    Py_TPFLAGS_BASETYPE, /* tp_flags */
    0, /* tp_doc */
    0, /* tp_traverse */
    0, /* tp_clear */
    0, /* tp_richcompare */
    0, /* tp_weaklistoffset */
    0, /* tp_iter */
    0, /* tp_iternext */
    Shoddy_methods, /* tp_methods */
    0, /* tp_members */
    0, /* tp_getset */
    0, /* tp_base */
    0, /* tp_dict */
    0, /* tp_descr_get */
    0, /* tp_descr_set */
    0, /* tp_dictoffset */
    (initproc) Shoddy_init, /* tp_init */
    0, /* tp_alloc */
    0, /* tp_new */
};

PyMODINIT_FUNC
initshoddy(void)
{
    PyObject *m;

    ShoddyType.tp_base = &PyList_Type;
    if (PyType_Ready(&ShoddyType) < 0)
        return;
}
    
```

```

    m = Py_InitModule3("shoddy", NULL, "Shoddy module");
    if (m == NULL)
        return;

    Py_INCREF(&ShoddyType);
    PyModule_AddObject(m, "Shoddy", (PyObject *) &ShoddyType);
}

```

As you can see, the source code closely resembles the Noddy examples in previous sections. We will break down the main differences between them.

```

typedef struct {
    PyListObject list;
    int state;
} Shoddy;

```

The primary difference for derived type objects is that the base type's object structure must be the first value. The base type will already include the `PyObject_HEAD()` at the beginning of its structure.

When a Python object is a Shoddy instance, its `PyObject*` pointer can be safely cast to both `PyListObject*` and `Shoddy*`.

```

static int
Shoddy_init(Shoddy *self, PyObject *args, PyObject *kwds)
{
    if (PyList_Type.tp_init((PyObject *)self, args, kwds) < 0)
        return -1;
    self->state = 0;
    return 0;
}

```

In the `__init__` method for our type, we can see how to call through to the `__init__` method of the base type.

This pattern is important when writing a type with custom `new` and `dealloc` methods. The `new` method should not actually create the memory for the object with `tp_alloc`, that will be handled by the base class when calling its `tp_new`.

When filling out the `PyTypeObject()` for the Shoddy type, you see a slot for `tp_base()`. Due to cross platform compiler issues, you can't fill that field directly with the `PyList_Type()`; it can be done later in the module's `init()` function.

```

PyMODINIT_FUNC
initshoddy(void)
{
    PyObject *m;

    ShoddyType.tp_base = &PyList_Type;
    if (PyType_Ready(&ShoddyType) < 0)
        return;

    m = Py_InitModule3("shoddy", NULL, "Shoddy module");
    if (m == NULL)
        return;

    Py_INCREF(&ShoddyType);
    PyModule_AddObject(m, "Shoddy", (PyObject *) &ShoddyType);
}

```

Before calling `PyType_Ready()`, the type structure must have the `tp_base` slot filled in. When we are deriving a new type, it is not necessary to fill out the `tp_alloc` slot with `PyType_GenericNew()` – the allocate function from the base type will be inherited.

After that, calling `PyType_Ready()` and adding the type object to the module is the same as with the basic Noddy examples.

## 2.2 Type Methods

This section aims to give a quick fly-by on the various type methods you can implement and what they do.

Here is the definition of `PyTypeObject`, with some fields only used in debug builds omitted:

```
typedef struct _typeobject {
    PyObject_VAR_HEAD
    char *tp_name; /* For printing, in format "<module>.<name>" */
    int tp_basicsize, tp_itemsize; /* For allocation */

    /* Methods to implement standard operations */

    destructor tp_dealloc;
    printfunc tp_print;
    getattrfunc tp_getattr;
    setattrfunc tp_setattr;
    cmpfunc tp_compare;
    reprfunc tp_repr;

    /* Method suites for standard classes */

    PyNumberMethods *tp_as_number;
    PySequenceMethods *tp_as_sequence;
    PyMappingMethods *tp_as_mapping;

    /* More standard operations (here for binary compatibility) */

    hashfunc tp_hash;
    ternaryfunc tp_call;
    reprfunc tp_str;
    getattrofunc tp_getattro;
    setattrofunc tp_setattro;

    /* Functions to access object as input/output buffer */
    PyBufferProcs *tp_as_buffer;

    /* Flags to define presence of optional/expanded features */
    long tp_flags;

    char *tp_doc; /* Documentation string */

    /* Assigned meaning in release 2.0 */
    /* call function for all accessible objects */
    traverseproc tp_traverse;

    /* delete references to contained objects */

```

```

inquiry tp_clear;

/* Assigned meaning in release 2.1 */
/* rich comparisons */
richcmpfunc tp_richcompare;

/* weak reference enabler */
long tp_weaklistoffset;

/* Added in release 2.2 */
/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;

/* Attribute descriptor and subclassing stuff */
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
struct _typeobject *tp_base;
PyObject *tp_dict;
descrgetfunc tp_descr_get;
descrsetfunc tp_descr_set;
long tp_dictoffset;
initproc tp_init;
allocfunc tp_alloc;
newfunc tp_new;
freefunc tp_free; /* Low-level free-memory routine */
inquiry tp_is_gc; /* For PyObject_IS_GC */
PyObject *tp_bases;
PyObject *tp_mro; /* method resolution order */
PyObject *tp_cache;
PyObject *tp_subclasses;
PyObject *tp_weaklist;

} PyTypeObject;

```

Now that's a *lot* of methods. Don't worry too much though - if you have a type you want to define, the chances are very good that you will only implement a handful of these.

As you probably expect by now, we're going to go over this and give more information about the various handlers. We won't go in the order they are defined in the structure, because there is a lot of historical baggage that impacts the ordering of the fields; be sure your type initialization keeps the fields in the right order! It's often easiest to find an example that includes all the fields you need (even if they're initialized to 0) and then change the values to suit your new type.

```
char *tp_name; /* For printing */
```

The name of the type - as mentioned in the last section, this will appear in various places, almost entirely for diagnostic purposes. Try to choose something that will be helpful in such a situation!

```
int tp_basicsize, tp_itemsize; /* For allocation */
```

These fields tell the runtime how much memory to allocate when new objects of this type are created. Python has some built-in support for variable length structures (think: strings, lists) which is where the `tp_itemsize` field comes in. This will be dealt with later.

```
char *tp_doc;
```

Here you can put a string (or its address) that you want returned when the Python script references `obj.__doc__` to retrieve the doc string.

Now we come to the basic type methods—the ones most extension types will implement.

## 2.2.1 Finalization and De-allocation

```
destructor tp_dealloc;
```

This function is called when the reference count of the instance of your type is reduced to zero and the Python interpreter wants to reclaim it. If your type has memory to free or other clean-up to perform, put it here. The object itself needs to be freed here as well. Here is an example of this function:

```
static void
newdatatype_dealloc(newdatatypeobject * obj)
{
    free(obj->obj_UnderlyingDatatypePtr);
    obj->ob_type->tp_free(obj);
}
```

One important requirement of the deallocator function is that it leaves any pending exceptions alone. This is important since deallocators are frequently called as the interpreter unwinds the Python stack; when the stack is unwound due to an exception (rather than normal returns), nothing is done to protect the deallocators from seeing that an exception has already been set. Any actions which a deallocator performs which may cause additional Python code to be executed may detect that an exception has been set. This can lead to misleading errors from the interpreter. The proper way to protect against this is to save a pending exception before performing the unsafe action, and restoring it when done. This can be done using the `PyErr_Fetch()` and `PyErr_Restore()` functions:

```
static void
my_dealloc(PyObject *obj)
{
    MyObject *self = (MyObject *) obj;
    PyObject *cbresult;

    if (self->my_callback != NULL) {
        PyObject *err_type, *err_value, *err_traceback;
        int have_error = PyErr_Occurred() ? 1 : 0;

        if (have_error)
            PyErr_Fetch(&err_type, &err_value, &err_traceback);

        cbresult = PyObject_CallObject(self->my_callback, NULL);
        if (cbresult == NULL)
            PyErr_WriteUnraisable(self->my_callback);
        else
            Py_DECREF(cbresult);

        if (have_error)
            PyErr_Restore(err_type, err_value, err_traceback);

        Py_DECREF(self->my_callback);
    }
    obj->ob_type->tp_free((PyObject*) self);
}
```

## 2.2.2 Object Presentation

In Python, there are three ways to generate a textual representation of an object: the `repr()` function (or equivalent back-tick syntax), the `str()` function, and the `print` statement. For most objects, the `print` statement is equivalent to the `str()` function, but it is possible to special-case printing to a `FILE*` if necessary; this should only be done if efficiency is identified as a problem and profiling suggests that creating a temporary string object to be written to a file is too expensive.

These handlers are all optional, and most types at most need to implement the `tp_str` and `tp_repr` handlers.

```
reprfunc tp_repr;
reprfunc tp_str;
printfunc tp_print;
```

The `tp_repr` handler should return a string object containing a representation of the instance for which it is called. Here is a simple example:

```
static PyObject *
newdatatype_repr(newdatatypeobject * obj)
{
    return PyString_FromFormat("Repr-ified_newdatatype{{size:%d}}",
                               obj->obj_UnderlyingDatatypePtr->size);
}
```

If no `tp_repr` handler is specified, the interpreter will supply a representation that uses the type's `tp_name` and a uniquely-identifying value for the object.

The `tp_str` handler is to `str()` what the `tp_repr` handler described above is to `repr()`; that is, it is called when Python code calls `str()` on an instance of your object. Its implementation is very similar to the `tp_repr` function, but the resulting string is intended for human consumption. If `tp_str` is not specified, the `tp_repr` handler is used instead.

Here is a simple example:

```
static PyObject *
newdatatype_str(newdatatypeobject * obj)
{
    return PyString_FromFormat("Stringified_newdatatype{{size:%d}}",
                               obj->obj_UnderlyingDatatypePtr->size);
}
```

The `print` function will be called whenever Python needs to “print” an instance of the type. For example, if ‘node’ is an instance of type `TreeNode`, then the `print` function is called when Python code calls:

```
print node
```

There is a `flags` argument and one flag, `Py_PRINT_RAW`, and it suggests that you print without string quotes and possibly without interpreting escape sequences.

The `print` function receives a file object as an argument. You will likely want to write to that file object.

Here is a sample `print` function:

```
static int
newdatatype_print(newdatatypeobject *obj, FILE *fp, int flags)
{
    if (flags & Py_PRINT_RAW) {
        fprintf(fp, "<{newdatatype object--size: %d}>",
               obj->obj_UnderlyingDatatypePtr->size);
    }
    else {
```

```

        fprintf(fp, "\\\"<{newdatatype object--size: %d}>\\\"",
                obj->obj_UnderlyingDatatypePtr->size);
    }
    return 0;
}

```

## 2.2.3 Attribute Management

For every object which can support attributes, the corresponding type must provide the functions that control how the attributes are resolved. There needs to be a function which can retrieve attributes (if any are defined), and another to set attributes (if setting attributes is allowed). Removing an attribute is a special case, for which the new value passed to the handler is *NULL*.

Python supports two pairs of attribute handlers; a type that supports attributes only needs to implement the functions for one pair. The difference is that one pair takes the name of the attribute as a `char*`, while the other accepts a `PyObject*`. Each type can use whichever pair makes more sense for the implementation's convenience.

```

getattrfunc  tp_getattr;          /* char * version */
setattrfunc  tp_setattr;
/* ... */
getattrrofunc tp_getattrofunc;   /* PyObject * version */
setattrofunc tp_setattrofunc;

```

If accessing attributes of an object is always a simple operation (this will be explained shortly), there are generic implementations which can be used to provide the `PyObject*` version of the attribute management functions. The actual need for type-specific attribute handlers almost completely disappeared starting with Python 2.2, though there are many examples which have not been updated to use some of the new generic mechanism that is available.

### Generic Attribute Management

New in version 2.2. Most extension types only use *simple* attributes. So, what makes the attributes simple? There are only a couple of conditions that must be met:

1. The name of the attributes must be known when `PyType_Ready()` is called.
2. No special processing is needed to record that an attribute was looked up or set, nor do actions need to be taken based on the value.

Note that this list does not place any restrictions on the values of the attributes, when the values are computed, or how relevant data is stored.

When `PyType_Ready()` is called, it uses three tables referenced by the type object to create *descriptors* which are placed in the dictionary of the type object. Each descriptor controls access to one attribute of the instance object. Each of the tables is optional; if all three are *NULL*, instances of the type will only have attributes that are inherited from their base type, and should leave the `tp_getattro` and `tp_setattro` fields *NULL* as well, allowing the base type to handle attributes.

The tables are declared as three fields of the type object:

```

struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;

```

If `tp_methods` is not *NULL*, it must refer to an array of `PyMethodDef` structures. Each entry in the table is an instance of this structure:

```

typedef struct PyMethodDef {
    char          *ml_name;          /* method name */

```

```

    PyCFunction ml_meth;      /* implementation function */
    int ml_flags;           /* flags */
    char *ml_doc;          /* docstring */
} PyMethodDef;

```

One entry should be defined for each method provided by the type; no entries are needed for methods inherited from a base type. One additional entry is needed at the end; it is a sentinel that marks the end of the array. The `ml_name` field of the sentinel must be `NULL`.

XXX Need to refer to some unified discussion of the structure fields, shared with the next section.

The second table is used to define attributes which map directly to data stored in the instance. A variety of primitive C types are supported, and access may be read-only or read-write. The structures in the table are defined as:

```

typedef struct PyMemberDef {
    char *name;
    int type;
    int offset;
    int flags;
    char *doc;
} PyMemberDef;

```

For each entry in the table, a *descriptor* will be constructed and added to the type which will be able to extract a value from the instance structure. The `type` field should contain one of the type codes defined in the `structmember.h` header; the value will be used to determine how to convert Python values to and from C values. The `flags` field is used to store flags which control how the attribute can be accessed.

XXX Need to move some of this to a shared section!

The following flag constants are defined in `structmember.h`; they may be combined using bitwise-OR.

| Constant         | Meaning                                      |
|------------------|----------------------------------------------|
| READONLY         | Never writable.                              |
| RO               | Shorthand for READONLY.                      |
| READ_RESTRICTED  | Not readable in restricted mode.             |
| WRITE_RESTRICTED | Not writable in restricted mode.             |
| RESTRICTED       | Not readable or writable in restricted mode. |

An interesting advantage of using the `tp_members` table to build descriptors that are used at runtime is that any attribute defined this way can have an associated doc string simply by providing the text in the table. An application can use the introspection API to retrieve the descriptor from the class object, and get the doc string using its `__doc__` attribute.

As with the `tp_methods` table, a sentinel entry with a `name` value of `NULL` is required.

## Type-specific Attribute Management

For simplicity, only the `char*` version will be demonstrated here; the type of the `name` parameter is the only difference between the `char*` and `PyObject*` flavors of the interface. This example effectively does the same thing as the generic example above, but does not use the generic support added in Python 2.2. The value in showing this is two-fold: it demonstrates how basic attribute management can be done in a way that is portable to older versions of Python, and explains how the handler functions are called, so that if you do need to extend their functionality, you'll understand what needs to be done.

The `tp_getattr` handler is called when the object requires an attribute look-up. It is called in the same situations where the `__getattr__()` method of a class would be called.

A likely way to handle this is (1) to implement a set of functions (such as `newdatatype_getSize()` and `newdatatype_setSize()` in the example below), (2) provide a method table listing these functions, and (3)

provide a `getattr` function that returns the result of a lookup in that table. The method table uses the same structure as the `tp_methods` field of the type object.

Here is an example:

```
static PyMethodDef newdatatype_methods[] = {
    {"getSize", (PyCFunction)newdatatype_getSize, METH_VARARGS,
     "Return the current size."},
    {"setSize", (PyCFunction)newdatatype_setSize, METH_VARARGS,
     "Set the size."},
    {NULL, NULL, 0, NULL}          /* sentinel */
};

static PyObject *
newdatatype_getattr(newdatatypeobject *obj, char *name)
{
    return Py_FindMethod(newdatatype_methods, (PyObject *)obj, name);
}
```

The `tp_setattr` handler is called when the `__setattr__()` or `__delattr__()` method of a class instance would be called. When an attribute should be deleted, the third parameter will be `NULL`. Here is an example that simply raises an exception; if this were really all you wanted, the `tp_setattr` handler should be set to `NULL`.

```
static int
newdatatype_setattr(newdatatypeobject *obj, char *name, PyObject *v)
{
    (void)PyErr_Format(PyExc_RuntimeError, "Read-only attribute: %s", name);
    return -1;
}
```

## 2.2.4 Object Comparison

```
cmpfunc tp_compare;
```

The `tp_compare` handler is called when comparisons are needed and the object does not implement the specific rich comparison method which matches the requested comparison. (It is always used if defined and the `PyObject_Compare()` or `PyObject_Cmp()` functions are used, or if `cmp()` is used from Python.) It is analogous to the `__cmp__()` method. This function should return `-1` if `obj1` is less than `obj2`, `0` if they are equal, and `1` if `obj1` is greater than `obj2`. (It was previously allowed to return arbitrary negative or positive integers for less than and greater than, respectively; as of Python 2.2, this is no longer allowed. In the future, other return values may be assigned a different meaning.)

A `tp_compare` handler may raise an exception. In this case it should return a negative value. The caller has to test for the exception using `PyErr_Occurred()`.

Here is a sample implementation:

```
static int
newdatatype_compare(newdatatypeobject * obj1, newdatatypeobject * obj2)
{
    long result;

    if (obj1->obj_UnderlyingDatatypePtr->size <
        obj2->obj_UnderlyingDatatypePtr->size) {
        result = -1;
    }
    else if (obj1->obj_UnderlyingDatatypePtr->size >
```

```

        obj2->obj_UnderlyingDatatypePtr->size) {
    result = 1;
}
else {
    result = 0;
}
return result;
}

```

## 2.2.5 Abstract Protocol Support

Python supports a variety of *abstract* ‘protocols;’ the specific interfaces provided to use these interfaces are documented in *abstract*.

A number of these abstract interfaces were defined early in the development of the Python implementation. In particular, the number, mapping, and sequence protocols have been part of Python since the beginning. Other protocols have been added over time. For protocols which depend on several handler routines from the type implementation, the older protocols have been defined as optional blocks of handlers referenced by the type object. For newer protocols there are additional slots in the main type object, with a flag bit being set to indicate that the slots are present and should be checked by the interpreter. (The flag bit does not indicate that the slot values are non-*NULL*. The flag may be set to indicate the presence of a slot, but a slot may still be unfilled.)

```

PyNumberMethods  tp_as_number;
PySequenceMethods tp_as_sequence;
PyMappingMethods tp_as_mapping;

```

If you wish your object to be able to act like a number, a sequence, or a mapping object, then you place the address of a structure that implements the C type `PyNumberMethods`, `PySequenceMethods`, or `PyMappingMethods`, respectively. It is up to you to fill in this structure with appropriate values. You can find examples of the use of each of these in the `Objects` directory of the Python source distribution.

```
hashfunc tp_hash;
```

This function, if you choose to provide it, should return a hash number for an instance of your data type. Here is a moderately pointless example:

```

static long
newdatatype_hash(newdatatypeobject *obj)
{
    long result;
    result = obj->obj_UnderlyingDatatypePtr->size;
    result = result * 3;
    return result;
}

```

```
ternaryfunc tp_call;
```

This function is called when an instance of your data type is “called”, for example, if `obj1` is an instance of your data type and the Python script contains `obj1('hello')`, the `tp_call` handler is invoked.

This function takes three arguments:

1. *arg1* is the instance of the data type which is the subject of the call. If the call is `obj1('hello')`, then *arg1* is `obj1`.
2. *arg2* is a tuple containing the arguments to the call. You can use `PyArg_ParseTuple()` to extract the arguments.

3. *arg3* is a dictionary of keyword arguments that were passed. If this is non-*NULL* and you support keyword arguments, use `PyArg_ParseTupleAndKeywords()` to extract the arguments. If you do not want to support keyword arguments and this is non-*NULL*, raise a `TypeError` with a message saying that keyword arguments are not supported.

Here is a desultory example of the implementation of the call function.

```

/* Implement the call function.
 *  obj1 is the instance receiving the call.
 *  obj2 is a tuple containing the arguments to the call, in this
 *     case 3 strings.
 */
static PyObject *
newdatatype_call(newdatatypeobject *obj, PyObject *args, PyObject *other)
{
    PyObject *result;
    char *arg1;
    char *arg2;
    char *arg3;

    if (!PyArg_ParseTuple(args, "sss:call", &arg1, &arg2, &arg3)) {
        return NULL;
    }
    result = PyString_FromFormat(
        "Returning -- value: [%d] arg1: [%s] arg2: [%s] arg3: [%s]\n",
        obj->obj_UnderlyingDatatypePtr->size,
        arg1, arg2, arg3);
    printf("%s", PyString_AS_STRING(result));
    return result;
}

```

XXX some fields need to be added here...

```

/* Added in release 2.2 */
/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;

```

These functions provide support for the iterator protocol. Any object which wishes to support iteration over its contents (which may be generated during iteration) must implement the `tp_iter` handler. Objects which are returned by a `tp_iter` handler must implement both the `tp_iter` and `tp_iternext` handlers. Both handlers take exactly one parameter, the instance for which they are being called, and return a new reference. In the case of an error, they should set an exception and return *NULL*.

For an object which represents an iterable collection, the `tp_iter` handler must return an iterator object. The iterator object is responsible for maintaining the state of the iteration. For collections which can support multiple iterators which do not interfere with each other (as lists and tuples do), a new iterator should be created and returned. Objects which can only be iterated over once (usually due to side effects of iteration) should implement this handler by returning a new reference to themselves, and should also implement the `tp_iternext` handler. File objects are an example of such an iterator.

Iterator objects should implement both handlers. The `tp_iter` handler should return a new reference to the iterator (this is the same as the `tp_iter` handler for objects which can only be iterated over destructively). The `tp_iternext` handler should return a new reference to the next object in the iteration if there is one. If the iteration has reached the end, it may return *NULL* without setting an exception or it may set `StopIteration`; avoiding the exception can yield slightly better performance. If an actual error occurs, it should set an exception and return *NULL*.

## 2.2.6 Weak Reference Support

One of the goals of Python's weak-reference implementation is to allow any type to participate in the weak reference mechanism without incurring the overhead on those objects which do not benefit by weak referencing (such as numbers).

For an object to be weakly referencable, the extension must include a `PyObject*` field in the instance structure for the use of the weak reference mechanism; it must be initialized to `NULL` by the object's constructor. It must also set the `tp_weaklistoffset` field of the corresponding type object to the offset of the field. For example, the instance type is defined with the following structure:

```
typedef struct {
    PyObject_HEAD
    PyClassObject *in_class;      /* The class object */
    PyObject      *in_dict;      /* A dictionary */
    PyObject      *in_weakreflist; /* List of weak references */
} PyInstanceObject;
```

The statically-declared type object for instances is defined this way:

```
PyTypeObject PyInstance_Type = {
    PyObject_HEAD_INIT(&PyType_Type)
    0,
    "module.instance",

    /* Lots of stuff omitted for brevity... */

    Py_TPFLAGS_DEFAULT,          /* tp_flags */
    0,                            /* tp_doc */
    0,                            /* tp_traverse */
    0,                            /* tp_clear */
    0,                            /* tp_richcompare */
    offsetof(PyInstanceObject, in_weakreflist), /* tp_weaklistoffset */
};
```

The type constructor is responsible for initializing the weak reference list to `NULL`:

```
static PyObject *
instance_new() {
    /* Other initialization stuff omitted for brevity */

    self->in_weakreflist = NULL;

    return (PyObject *) self;
}
```

The only further addition is that the destructor needs to call the weak reference manager to clear any weak references. This is only required if the weak reference list is non-`NULL`:

```
static void
instance_dealloc(PyInstanceObject *inst)
{
    /* Allocate temporaries if needed, but do not begin
       destruction just yet.
    */

    if (inst->in_weakreflist != NULL)
        PyObject_ClearWeakRefs((PyObject *) inst);
}
```

```

    /* Proceed with object destruction normally. */
}

```

## 2.2.7 More Suggestions

Remember that you can omit most of these functions, in which case you provide 0 as a value. There are type definitions for each of the functions you must provide. They are in `object.h` in the Python include directory that comes with the source distribution of Python.

In order to learn how to implement any specific method for your new data type, do the following: Download and unpack the Python source distribution. Go the `Objects` directory, then search the C source files for `tp_` plus the function you want (for example, `tp_print` or `tp_compare`). You will find examples of the function you want to implement.

When you need to verify that an object is an instance of the type you are implementing, use the `PyObject_TypeCheck()` function. A sample of its use might be something like the following:

```

if (! PyObject_TypeCheck(some_object, &MyType)) {
    PyErr_SetString(PyExc_TypeError, "arg #1 not a mything");
    return NULL;
}

```



# BUILDING C AND C++ EXTENSIONS WITH DISTUTILS

Starting in Python 1.4, Python provides, on Unix, a special make file for building make files for building dynamically-linked extensions and custom interpreters. Starting with Python 2.0, this mechanism (known as related to Makefile.pre.in, and Setup files) is no longer supported. Building custom interpreters was rarely used, and extension modules can be built using distutils.

Building an extension module using distutils requires that distutils is installed on the build machine, which is included in Python 2.x and available separately for Python 1.5. Since distutils also supports creation of binary packages, users don't necessarily need a compiler and distutils to install the extension.

A distutils package contains a driver script, `setup.py`. This is a plain Python file, which, in the most simple case, could look like this:

```
from distutils.core import setup, Extension

module1 = Extension('demo',
                    sources = ['demo.c'])

setup (name = 'PackageName',
       version = '1.0',
       description = 'This is a demo package',
       ext_modules = [module1])
```

With this `setup.py`, and a file `demo.c`, running

```
python setup.py build
```

will compile `demo.c`, and produce an extension module named `demo` in the build directory. Depending on the system, the module file will end up in a subdirectory `build/lib.system`, and may have a name like `demo.so` or `demo.pyd`.

In the `setup.py`, all execution is performed by calling the `setup` function. This takes a variable number of keyword arguments, of which the example above uses only a subset. Specifically, the example specifies meta-information to build packages, and it specifies the contents of the package. Normally, a package will contain of addition modules, like Python source modules, documentation, subpackages, etc. Please refer to the distutils documentation in *distutils-index* to learn more about the features of distutils; this section explains building extension modules only.

It is common to pre-compute arguments to `setup()`, to better structure the driver script. In the example above, the `ext_modules` argument to `setup()` is a list of extension modules, each of which is an instance of the `Extension`. In the example, the instance defines an extension named `demo` which is build by compiling a single source file, `demo.c`.

In many cases, building an extension is more complex, since additional preprocessor defines and libraries may be needed. This is demonstrated in the example below.

```
from distutils.core import setup, Extension

module1 = Extension('demo',
                    define_macros = [('MAJOR_VERSION', '1'),
                                     ('MINOR_VERSION', '0')],
                    include_dirs = ['/usr/local/include'],
                    libraries = ['tcl83'],
                    library_dirs = ['/usr/local/lib'],
                    sources = ['demo.c'])

setup (name = 'PackageName',
      version = '1.0',
      description = 'This is a demo package',
      author = 'Martin v. Loewis',
      author_email = 'martin@v.loewis.de',
      url = 'http://docs.python.org/extending/building',
      long_description = '''
This is really just a demo package.
''',
      ext_modules = [module1])
```

In this example, `setup()` is called with additional meta-information, which is recommended when distribution packages have to be built. For the extension itself, it specifies preprocessor defines, include directories, library directories, and libraries. Depending on the compiler, `distutils` passes this information in different ways to the compiler. For example, on Unix, this may result in the compilation commands

```
gcc -DNDEBUG -g -O3 -Wall -Wstrict-prototypes -fPIC -DMAJOR_VERSION=1 -DMINOR_VERSION=0 -I...
gcc -shared build/temp.linux-i686-2.2/demo.o -L/usr/local/lib -ltcl83 -o build/lib.linux-i...
```

These lines are for demonstration purposes only; `distutils` users should trust that `distutils` gets the invocations right.

### 3.1 Distributing your extension modules

When an extension has been successfully build, there are three ways to use it.

End-users will typically want to install the module, they do so by running

```
python setup.py install
```

Module maintainers should produce source packages; to do so, they run

```
python setup.py sdist
```

In some cases, additional files need to be included in a source distribution; this is done through a `MANIFEST.in` file; see the `distutils` documentation for details.

If the source distribution has been build successfully, maintainers can also create binary distributions. Depending on the platform, one of the following commands can be used to do so.

```
python setup.py bdist_wininst
python setup.py bdist_rpm
python setup.py bdist_dumb
```

# BUILDING C AND C++ EXTENSIONS ON WINDOWS

This chapter briefly explains how to create a Windows extension module for Python using Microsoft Visual C++, and follows with more detailed background information on how it works. The explanatory material is useful for both the Windows programmer learning to build Python extensions and the Unix programmer interested in producing software which can be successfully built on both Unix and Windows.

Module authors are encouraged to use the `distutils` approach for building extension modules, instead of the one described in this section. You will still need the C compiler that was used to build Python; typically Microsoft Visual C++.

---

**Note:** This chapter mentions a number of filenames that include an encoded Python version number. These filenames are represented with the version number shown as `XY`; in practice, 'X' will be the major version number and 'Y' will be the minor version number of the Python release you're working with. For example, if you are using Python 2.2.1, `XY` will actually be `22`.

---

## 4.1 A Cookbook Approach

There are two approaches to building extension modules on Windows, just as there are on Unix: use the `distutils` package to control the build process, or do things manually. The `distutils` approach works well for most extensions; documentation on using `distutils` to build and package extension modules is available in `distutils-index`. This section describes the manual approach to building Python extensions written in C or C++.

To build extensions using these instructions, you need to have a copy of the Python sources of the same version as your installed Python. You will need Microsoft Visual C++ "Developer Studio"; project files are supplied for VC++ version 7.1, but you can use older versions of VC++. Notice that you should use the same version of VC++ that was used to build Python itself. The example files described here are distributed with the Python sources in the `PC\example_nt\` directory.

1. **Copy the example files** — The `example_nt` directory is a subdirectory of the `PC` directory, in order to keep all the PC-specific files under the same directory in the source distribution. However, the `example_nt` directory can't actually be used from this location. You first need to copy or move it up one level, so that `example_nt` is a sibling of the `PC` and `Include` directories. Do all your work from within this new location.
2. **Open the project** — From VC++, use the *File* → *Open Solution* dialog (not *File* → *Open!*). Navigate to and select the file `example.sln`, in the *copy* of the `example_nt` directory you made above. Click *Open*.
3. **Build the example DLL** — In order to check that everything is set up right, try building:

4. Select a configuration. This step is optional. Choose *Build* → *Configuration Manager* → *Active Solution Configuration* and select either *Release* or *Debug*. If you skip this step, VC++ will use the Debug configuration by default.
5. Build the DLL. Choose *Build* → *Build Solution*. This creates all intermediate and result files in a subdirectory called either *Debug* or *Release*, depending on which configuration you selected in the preceding step.
6. **Testing the debug-mode DLL** — Once the Debug build has succeeded, bring up a DOS box, and change to the `example_nt\Debug` directory. You should now be able to repeat the following session (C> is the DOS prompt, >>> is the Python prompt; note that build information and various debug output from Python may not match this screen dump exactly):

```
C>..\..\PCbuild\python_d
Adding parser accelerators ...
Done.
Python 2.2 (#28, Dec 19 2001, 23:26:37) [MSC 32 bit (Intel)] on win32
Type "copyright", "credits" or "license" for more information.
>>> import example
[4897 refs]
>>> example.foo()
Hello, world
[4903 refs]
>>>
```

Congratulations! You've successfully built your first Python extension module.

7. **Creating your own project** — Choose a name and create a directory for it. Copy your C sources into it. Note that the module source file name does not necessarily have to match the module name, but the name of the initialization function should match the module name — you can only import a module `spam` if its initialization function is called `initspam()`, and it should call `Py_InitModule()` with the string "spam" as its first argument (use the minimal `example.c` in this directory as a guide). By convention, it lives in a file called `spam.c` or `spammodule.c`. The output file should be called `spam.pyd` (in Release mode) or `spam_d.pyd` (in Debug mode). The extension `.pyd` was chosen to avoid confusion with a system library `spam.dll` to which your module could be a Python interface. Changed in version 2.5: Previously, file names like `spam.dll` (in release mode) or `spam_d.dll` (in debug mode) were also recognized. Now your options are:
8. Copy `example.sln` and `example.vcproj`, rename them to `spam.*`, and edit them by hand, or
9. Create a brand new project; instructions are below.

In either case, copy `example_nt\example.def` to `spam\spam.def`, and edit the new `spam.def` so its second line contains the string 'initspam'. If you created a new project yourself, add the file `spam.def` to the project now. (This is an annoying little file with only two lines. An alternative approach is to forget about the `.def` file, and add the option `/export:initspam` somewhere to the Link settings, by manually editing the setting in Project Properties dialog).

10. **Creating a brand new project** — Use the *File* → *New* → *Project* dialog to create a new Project Workspace. Select *Visual C++ Projects/Win32/ Win32 Project*, enter the name (`spam`), and make sure the Location is set to parent of the `spam` directory you have created (which should be a direct subdirectory of the Python build tree, a sibling of `Include` and `PC`). Select `Win32` as the platform (in my version, this is the only choice). Make sure the *Create new workspace* radio button is selected. Click OK.

You should now create the file `spam.def` as instructed in the previous section. Add the source files to the project, using *Project* → *Add Existing Item*. Set the pattern to `*.*` and select both `spam.c` and `spam.def` and click OK. (Inserting them one by one is fine too.)

Now open the *Project* → *spam properties* dialog. You only need to change a few settings. Make sure *All Configurations* is selected from the *Settings for:* dropdown list. Select the *C/C++* tab. Choose the *General*

category in the popup menu at the top. Type the following text in the entry box labeled *Additional Include Directories*:

```
..\Include,..\PC
```

Then, choose the General category in the Linker tab, and enter

```
..\PCbuild
```

in the text box labelled *Additional library Directories*.

Now you need to add some mode-specific settings:

Select *Release* in the *Configuration* dropdown list. Choose the *Link* tab, choose the *Input* category, and append `pythonXY.lib` to the list in the *Additional Dependencies* box.

Select *Debug* in the *Configuration* dropdown list, and append `pythonXY_d.lib` to the list in the *Additional Dependencies* box. Then click the *C/C++* tab, select *Code Generation*, and select *Multi-threaded Debug DLL* from the *Runtime library* dropdown list.

Select *Release* again from the *Configuration* dropdown list. Select *Multi-threaded DLL* from the *Runtime library* dropdown list.

If your module creates a new type, you may have trouble with this line:

```
PyObject_HEAD_INIT(&PyType_Type)
```

Static type object initializers in extension modules may cause compiles to fail with an error message like “initializer not a constant”. This shows up when building DLL under MSVC. Change it to:

```
PyObject_HEAD_INIT(NULL)
```

and add the following to the module initialization function:

```
if (PyType_Ready(&MyObject_Type) < 0)
    return NULL;
```

## 4.2 Differences Between Unix and Windows

Unix and Windows use completely different paradigms for run-time loading of code. Before you try to build a module that can be dynamically loaded, be aware of how your system works.

In Unix, a shared object (`.so`) file contains code to be used by the program, and also the names of functions and data that it expects to find in the program. When the file is joined to the program, all references to those functions and data in the file’s code are changed to point to the actual locations in the program where the functions and data are placed in memory. This is basically a link operation.

In Windows, a dynamic-link library (`.dll`) file has no dangling references. Instead, an access to functions or data goes through a lookup table. So the DLL code does not have to be fixed up at runtime to refer to the program’s memory; instead, the code already uses the DLL’s lookup table, and the lookup table is modified at runtime to point to the functions and data.

In Unix, there is only one type of library file (`.a`) which contains code from several object files (`.o`). During the link step to create a shared object file (`.so`), the linker may find that it doesn’t know where an identifier is defined. The linker will look for it in the object files in the libraries; if it finds it, it will include all the code from that object file.

In Windows, there are two types of library, a static library and an import library (both called `.lib`). A static library is like a Unix `.a` file; it contains code to be included as necessary. An import library is basically used only to reassure the linker that a certain identifier is legal, and will be present in the program when the DLL is loaded. So the linker uses the information from the import library to build the lookup table for using identifiers that are not included in the

DLL. When an application or a DLL is linked, an import library may be generated, which will need to be used for all future DLLs that depend on the symbols in the application or DLL.

Suppose you are building two dynamic-load modules, B and C, which should share another block of code A. On Unix, you would *not* pass `A.a` to the linker for `B.so` and `C.so`; that would cause it to be included twice, so that B and C would each have their own copy. In Windows, building `A.dll` will also build `A.lib`. You *do* pass `A.lib` to the linker for B and C. `A.lib` does not contain code; it just contains information which will be used at runtime to access A's code.

In Windows, using an import library is sort of like using `import spam`; it gives you access to `spam`'s names, but does not create a separate copy. On Unix, linking with a library is more like `from spam import *`; it does create a separate copy.

### 4.3 Using DLLs in Practice

Windows Python is built in Microsoft Visual C++; using other compilers may or may not work (though Borland seems to). The rest of this section is MSVC++ specific.

When creating DLLs in Windows, you must pass `pythonXY.lib` to the linker. To build two DLLs, `spam` and `ni` (which uses C functions found in `spam`), you could use these commands:

```
cl /LD /I/python/include spam.c ../libs/pythonXY.lib
cl /LD /I/python/include ni.c spam.lib ../libs/pythonXY.lib
```

The first command created three files: `spam.obj`, `spam.dll` and `spam.lib`. `Spam.dll` does not contain any Python functions (such as `PyArg_ParseTuple()`), but it does know how to find the Python code thanks to `pythonXY.lib`.

The second command created `ni.dll` (and `.obj` and `.lib`), which knows how to find the necessary functions from `spam`, and also from the Python executable.

Not every identifier is exported to the lookup table. If you want any other modules (including Python) to be able to see your identifiers, you have to say `_declspec(dllexport)`, as in `void _declspec(dllexport) initspam(void)` or `PyObject _declspec(dllexport) *NiGetSpamData(void)`.

Developer Studio will throw in a lot of import libraries that you do not really need, adding about 100K to your executable. To get rid of them, use the Project Settings dialog, Link tab, to specify *ignore default libraries*. Add the correct `msvcrtxx.lib` to the list of libraries.

# EMBEDDING PYTHON IN ANOTHER APPLICATION

The previous chapters discussed how to extend Python, that is, how to extend the functionality of Python by attaching a library of C functions to it. It is also possible to do it the other way around: enrich your C/C++ application by embedding Python in it. Embedding provides your application with the ability to implement some of the functionality of your application in Python rather than C or C++. This can be used for many purposes; one example would be to allow users to tailor the application to their needs by writing some scripts in Python. You can also use it yourself if some of the functionality can be written in Python more easily.

Embedding Python is similar to extending it, but not quite. The difference is that when you extend Python, the main program of the application is still the Python interpreter, while if you embed Python, the main program may have nothing to do with Python — instead, some parts of the application occasionally call the Python interpreter to run some Python code.

So if you are embedding Python, you are providing your own main program. One of the things this main program has to do is initialize the Python interpreter. At the very least, you have to call the function `Py_Initialize()`. There are optional calls to pass command line arguments to Python. Then later you can call the interpreter from any part of the application.

There are several different ways to call the interpreter: you can pass a string containing Python statements to `PyRun_SimpleString()`, or you can pass a stdio file pointer and a file name (for identification in error messages only) to `PyRun_SimpleFile()`. You can also call the lower-level operations described in the previous chapters to construct and use Python objects.

A simple demo of embedding Python can be found in the directory `Demo/embed/` of the source distribution.

## See Also:

*c-api-index* The details of Python's C interface are given in this manual. A great deal of necessary information can be found here.

## 5.1 Very High Level Embedding

The simplest form of embedding Python is the use of the very high level interface. This interface is intended to execute a Python script without needing to interact with the application directly. This can for example be used to perform some operation on a file.

```
#include <Python.h>
```

```
int  
main(int argc, char *argv[])
```

```
{
    Py_Initialize();
    PyRun_SimpleString("from time import time,ctime\n"
                      "print 'Today is',ctime(time())\n");
    Py_Finalize();
    return 0;
}
```

The above code first initializes the Python interpreter with `Py_Initialize()`, followed by the execution of a hard-coded Python script that print the date and time. Afterwards, the `Py_Finalize()` call shuts the interpreter down, followed by the end of the program. In a real program, you may want to get the Python script from another source, perhaps a text-editor routine, a file, or a database. Getting the Python code from a file can better be done by using the `PyRun_SimpleFile()` function, which saves you the trouble of allocating memory space and loading the file contents.

## 5.2 Beyond Very High Level Embedding: An overview

The high level interface gives you the ability to execute arbitrary pieces of Python code from your application, but exchanging data values is quite cumbersome to say the least. If you want that, you should use lower level calls. At the cost of having to write more C code, you can achieve almost anything.

It should be noted that extending Python and embedding Python is quite the same activity, despite the different intent. Most topics discussed in the previous chapters are still valid. To show this, consider what the extension code from Python to C really does:

1. Convert data values from Python to C,
2. Perform a function call to a C routine using the converted values, and
3. Convert the data values from the call from C to Python.

When embedding Python, the interface code does:

1. Convert data values from C to Python,
2. Perform a function call to a Python interface routine using the converted values, and
3. Convert the data values from the call from Python to C.

As you can see, the data conversion steps are simply swapped to accommodate the different direction of the cross-language transfer. The only difference is the routine that you call between both data conversions. When extending, you call a C routine, when embedding, you call a Python routine.

This chapter will not discuss how to convert data from Python to C and vice versa. Also, proper use of references and dealing with errors is assumed to be understood. Since these aspects do not differ from extending the interpreter, you can refer to earlier chapters for the required information.

## 5.3 Pure Embedding

The first program aims to execute a function in a Python script. Like in the section about the very high level interface, the Python interpreter does not directly interact with the application (but that will change in the next section).

The code to run a function defined in a Python script is:

```
#include <Python.h>
```

```
int
```

```

main(int argc, char *argv[])
{
    PyObject *pName, *pModule, *pDict, *pFunc;
    PyObject *pArgs, *pValue;
    int i;

    if (argc < 3) {
        fprintf(stderr, "Usage: call pythonfile funcname [args]\n");
        return 1;
    }

    Py_Initialize();
    pName = PyString_FromString(argv[1]);
    /* Error checking of pName left out */

    pModule = PyImport_Import(pName);
    Py_DECREF(pName);

    if (pModule != NULL) {
        pFunc = PyObject_GetAttrString(pModule, argv[2]);
        /* pFunc is a new reference */

        if (pFunc && PyCallable_Check(pFunc)) {
            pArgs = PyTuple_New(argc - 3);
            for (i = 0; i < argc - 3; ++i) {
                pValue = PyInt_FromLong(atoi(argv[i + 3]));
                if (!pValue) {
                    Py_DECREF(pArgs);
                    Py_DECREF(pModule);
                    fprintf(stderr, "Cannot convert argument\n");
                    return 1;
                }
                /* pValue reference stolen here: */
                PyTuple_SetItem(pArgs, i, pValue);
            }
            pValue = PyObject_CallObject(pFunc, pArgs);
            Py_DECREF(pArgs);
            if (pValue != NULL) {
                printf("Result of call: %ld\n", PyInt_AsLong(pValue));
                Py_DECREF(pValue);
            }
            else {
                Py_DECREF(pFunc);
                Py_DECREF(pModule);
                PyErr_Print();
                fprintf(stderr, "Call failed\n");
                return 1;
            }
        }
        else {
            if (PyErr_Occurred())
                PyErr_Print();
            fprintf(stderr, "Cannot find function \"%s\"\n", argv[2]);
        }
    }
}

```

```
    Py_XDECREF(pFunc);
    Py_DECREF(pModule);
}
else {
    PyErr_Print();
    fprintf(stderr, "Failed to load \"%s\"\n", argv[1]);
    return 1;
}
Py_Finalize();
return 0;
}
```

This code loads a Python script using `argv[1]`, and calls the function named in `argv[2]`. Its integer arguments are the other values of the `argv` array. If you compile and link this program (let's call the finished executable **call**), and use it to execute a Python script, such as:

```
def multiply(a,b):
    print "Will compute", a, "times", b
    c = 0
    for i in range(0, a):
        c = c + b
    return c
```

then the result should be:

```
$ call multiply multiply 3 2
Will compute 3 times 2
Result of call: 6
```

Although the program is quite large for its functionality, most of the code is for data conversion between Python and C, and for error reporting. The interesting part with respect to embedding Python starts with

```
Py_Initialize();
pName = PyString_FromString(argv[1]);
/* Error checking of pName left out */
pModule = PyImport_Import(pName);
```

After initializing the interpreter, the script is loaded using `PyImport_Import()`. This routine needs a Python string as its argument, which is constructed using the `PyString_FromString()` data conversion routine.

```
pFunc = PyObject_GetAttrString(pModule, argv[2]);
/* pFunc is a new reference */
```

```
if (pFunc && PyCallable_Check(pFunc)) {
    ...
}
Py_XDECREF(pFunc);
```

Once the script is loaded, the name we're looking for is retrieved using `PyObject_GetAttrString()`. If the name exists, and the object returned is callable, you can safely assume that it is a function. The program then proceeds by constructing a tuple of arguments as normal. The call to the Python function is then made with:

```
pValue = PyObject_CallObject(pFunc, pArgs);
```

Upon return of the function, `pValue` is either `NULL` or it contains a reference to the return value of the function. Be sure to release the reference after examining the value.

## 5.4 Extending Embedded Python

Until now, the embedded Python interpreter had no access to functionality from the application itself. The Python API allows this by extending the embedded interpreter. That is, the embedded interpreter gets extended with routines provided by the application. While it sounds complex, it is not so bad. Simply forget for a while that the application starts the Python interpreter. Instead, consider the application to be a set of subroutines, and write some glue code that gives Python access to those routines, just like you would write a normal Python extension. For example:

```
static int numargs=0;

/* Return the number of arguments of the application command line */
static PyObject*
emb_numargs(PyObject *self, PyObject *args)
{
    if(!PyArg_ParseTuple(args, ":numargs"))
        return NULL;
    return Py_BuildValue("i", numargs);
}

static PyMethodDef EmbMethods[] = {
    {"numargs", emb_numargs, METH_VARARGS,
     "Return the number of arguments received by the process."},
    {NULL, NULL, 0, NULL}
};
```

Insert the above code just above the `main()` function. Also, insert the following two statements directly after `Py_Initialize()`:

```
numargs = argc;
Py_InitModule("emb", EmbMethods);
```

These two lines initialize the `numargs` variable, and make the `emb.numargs()` function accessible to the embedded Python interpreter. With these extensions, the Python script can do things like

```
import emb
print "Number of arguments", emb.numargs()
```

In a real application, the methods will expose an API of the application to Python.

## 5.5 Embedding Python in C++

It is also possible to embed Python in a C++ program; precisely how this is done will depend on the details of the C++ system used; in general you will need to write the main program in C++, and use the C++ compiler to compile and link your program. There is no need to recompile Python itself using C++.

## 5.6 Linking Requirements

While the `configure` script shipped with the Python sources will correctly build Python to export the symbols needed by dynamically linked extensions, this is not automatically inherited by applications which embed the Python library statically, at least on Unix. This is an issue when the application is linked to the static runtime library (`libpython.a`) and needs to load dynamic extensions (implemented as `.so` files).

The problem is that some entry points are defined by the Python runtime solely for extension modules to use. If the embedding application does not use any of these entry points, some linkers will not include those entries in the symbol table of the finished executable. Some additional options are needed to inform the linker not to remove these symbols.

Determining the right options to use for any given platform can be quite difficult, but fortunately the Python configuration already has those values. To retrieve them from an installed Python interpreter, start an interactive interpreter and have a short session like this:

```
>>> import distutils.sysconfig
>>> distutils.sysconfig.get_config_var('LINKFORSHARED')
'-Xlinker -export-dynamic'
```

The contents of the string presented will be the options that should be used. If the string is empty, there's no need to add any additional options. The `LINKFORSHARED` definition corresponds to the variable of the same name in Python's top-level `Makefile`.

---

# GLOSSARY

**>>>** The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

**. . .** The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

**2to3** A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3-reference*.

**abstract base class** Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections` module), numbers (in the `numbers` module), and streams (in the `io` module). You can create your own ABCs with the `abc` module.

**argument** A value passed to a function or method, assigned to a named local variable in the function body. A function or method may have both positional arguments and keyword arguments in its definition. Positional and keyword arguments may be variable-length: `*` accepts or passes (if in the function definition or call) several positional arguments in a list, while `**` does the same for keyword arguments in a dictionary.

Any expression may be used within the argument list, and the evaluated value is passed to the local variable.

**attribute** A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

**BDFL** Benevolent Dictator For Life, a.k.a. [Guido van Rossum](#), Python's creator.

**bytecode** Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` and `.pyo` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

**class** A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**coercion** The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number** An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of  $-1$ ), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager** An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](#).

**CPython** The canonical implementation of the Python programming language, as distributed on [python.org](http://python.org). The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator** A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

**descriptor** Any *new-style* object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using `a.b` to get, set or delete an attribute looks up the object named `b` in the class dictionary for `a`, but if `b` is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *descriptors*.

**dictionary** An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

**docstring** A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing** A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note,

however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

**EAFP** Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LYBL* style common to many other languages such as C.

**expression** A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statements* which cannot be used as expressions, such as `print` or `if`. Assignments are also statements, not expressions.

**extension module** A module written in C or C++, using Python's C API to interact with the core and with user code.

**file object** An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object** A synonym for *file object*.

**finder** An object that tries to find the *loader* for a module. It must implement a method named `find_module()`. See **PEP 302** for details.

**floor division** Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

**function** A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also *argument* and *method*.

**\_\_future\_\_** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it will become the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection** The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

**generator** A function which returns an iterator. It looks like a normal function except that it contains `yield` statements for producing a series a values usable in a `for`-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending `try`-statements). When the generator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression** An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))          # sum of squares 0, 1, 4, ... 81
285
```

**GIL** See *global interpreter lock*.

**global interpreter lock** The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable** An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` or `__cmp__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their `id()`.

**IDLE** An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable** An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**integer division** Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also `__future__`.

**importer** An object that both finds and loads a module; both a *finder* and *loader* object.

**interactive** Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

**interpreted** Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

**iterable** An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict` and `file` and objects of any classes you define with an `__iter__()` or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an

argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

**iterator** An object representing a stream of data. Repeated calls to the iterator's `next()` method return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `next()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *typeiter*.

**key function** A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, an ad-hoc key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the *Sorting HOW TO* for examples of how to create and use key functions.

**keyword argument** Arguments which are preceded with a `variable_name=` in the call. The variable name designates the local name in the function to which the value is assigned. `**` is used to accept or pass a dictionary of keyword arguments. See *argument*.

**lambda** An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL** Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the *EAFP* approach.

**list** A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are  $O(1)$ .

**list comprehension** A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ["0x%02x" % x for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

**loader** An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details.

**mapping** A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping *abstract base classes*. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

**metaclass** The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *metaclasses*.

**method** A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

**method resolution order** Method Resolution Order is the order in which base classes are searched for a member during lookup. See [The Python 2.3 Method Resolution Order](#).

**MRO** See *method resolution order*.

**mutable** Mutable objects can change their value but keep their `id()`. See also *immutable*.

**named tuple** Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

**namespace** The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `__builtin__.open()` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**nested scope** The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattr__()`.

More information can be found in *newstyle*.

**object** Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

**positional argument** The arguments assigned to local names inside a function or method, determined by the order in which they were given in the call. `*` is used to either accept multiple positional arguments (when in the definition), or pass several arguments as a list to a function. See *argument*.

**Python 3000** Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

**Pythonic** An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print food[i]
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print piece
```

**reference count** The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**\_\_slots\_\_** A declaration inside a *new-style class* that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence** An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `len()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `unicode`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

**slice** An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally (or in older versions, `__getslice__()` and `__setslice__()`).

**special method** A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *specialnames*.

**statement** A statement is part of a suite (a “block” of code). A statement is either an *expression* or a one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence** A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

**triple-quoted string** A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

**type** The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

**universal newlines** A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old Macintosh convention `'\r'`. See [PEP 278](#) and [PEP 3116](#), as well as `str.splitlines()` for an additional use.

**view** The objects returned from `dict.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` are called dictionary views. They are lazy sequences that will see changes in the underlying dictionary. To force the dictionary view to become a full list use `list(dictview)`. See *dict-views*.

**virtual machine** A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

**Zen of Python** Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing `import this` at the interactive prompt.

# ABOUT THESE DOCUMENTS

These documents are generated from [reStructuredText](#) sources by [Sphinx](#), a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain takes place on the [docs@python.org](mailto:docs@python.org) mailing list. We're always looking for volunteers wanting to help with the docs, so feel free to send a mail there!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the [Docutils](#) project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his [Alternative Python Reference](#) project from which Sphinx got many good ideas.

See *reporting-bugs* for information how to report bugs in this documentation, or Python itself.

## B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See [Misc/ACKS](#) in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!



# HISTORY AND LICENSE

## C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see <http://www.cwi.nl/>) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see <http://www.cnri.reston.va.us/>) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see <http://www.zope.com/>). In 2001, the Python Software Foundation (PSF, see <http://www.python.org/psf/>) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see <http://www.opensource.org/> for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

| Release        | Derived from | Year      | Owner      | GPL compatible? |
|----------------|--------------|-----------|------------|-----------------|
| 0.9.0 thru 1.2 | n/a          | 1991-1995 | CWI        | yes             |
| 1.3 thru 1.5.2 | 1.2          | 1995-1999 | CNRI       | yes             |
| 1.6            | 1.5.2        | 2000      | CNRI       | no              |
| 2.0            | 1.6          | 2000      | BeOpen.com | no              |
| 1.6.1          | 1.6          | 2001      | CNRI       | no              |
| 2.1            | 2.0+1.6.1    | 2001      | PSF        | no              |
| 2.0.1          | 2.0+1.6.1    | 2001      | PSF        | yes             |
| 2.1.1          | 2.1+2.0.1    | 2001      | PSF        | yes             |
| 2.2            | 2.1.1        | 2001      | PSF        | yes             |
| 2.1.2          | 2.1.1        | 2002      | PSF        | yes             |
| 2.1.3          | 2.1.2        | 2002      | PSF        | yes             |
| 2.2.1          | 2.2          | 2002      | PSF        | yes             |
| 2.2.2          | 2.2.1        | 2002      | PSF        | yes             |
| 2.2.3          | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3            | 2.2.2        | 2002-2003 | PSF        | yes             |
| 2.3.1          | 2.3          | 2002-2003 | PSF        | yes             |
| 2.3.2          | 2.3.1        | 2003      | PSF        | yes             |
| 2.3.3          | 2.3.2        | 2003      | PSF        | yes             |
| 2.3.4          | 2.3.3        | 2004      | PSF        | yes             |
| 2.3.5          | 2.3.4        | 2005      | PSF        | yes             |
| 2.4            | 2.3          | 2004      | PSF        | yes             |

Continued on next page

Table C.1 – continued from previous page

|       |       |      |     |     |
|-------|-------|------|-----|-----|
| 2.4.1 | 2.4   | 2005 | PSF | yes |
| 2.4.2 | 2.4.1 | 2005 | PSF | yes |
| 2.4.3 | 2.4.2 | 2006 | PSF | yes |
| 2.4.4 | 2.4.3 | 2006 | PSF | yes |
| 2.5   | 2.4   | 2006 | PSF | yes |
| 2.5.1 | 2.5   | 2007 | PSF | yes |
| 2.5.2 | 2.5.1 | 2008 | PSF | yes |
| 2.5.3 | 2.5.2 | 2008 | PSF | yes |
| 2.6   | 2.5   | 2008 | PSF | yes |
| 2.6.1 | 2.6   | 2008 | PSF | yes |
| 2.6.2 | 2.6.1 | 2009 | PSF | yes |
| 2.6.3 | 2.6.2 | 2009 | PSF | yes |
| 2.6.4 | 2.6.3 | 2010 | PSF | yes |
| 2.7   | 2.6   | 2010 | PSF | yes |

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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.
```

```
Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).
```

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Any feedback is very welcome.
http://www.math.keio.ac.jp/matumoto/emt.html
email: matumoto@math.keio.ac.jp
```

### C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, <http://www.wide.ad.jp/>.

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```
L. Peter Deutsch
ghost@aladdin.com
```

```
Independent implementation of MD5 (RFC 1321).
```

```
This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
```

```
http://www.ietf.org/rfc/rfc1321.txt
```

```
The code is derived from the text of the RFC, including the test suite
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```

```
The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>. Other authors are noted in the change history
that follows (in reverse chronological order):
```

- ```
2002-04-13 lpd Removed support for non-ANSI compilers; removed
           references to Ghostscript; clarified derivation from RFC 1321;
           now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
```

added conditionalization for C++ compilation from Martin Purschke <purschke@bnl.gov>. 1999-05-03 lpd Original version.

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http://zooko.com/  
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Modified by Jack Jansen, CWI, July 1995:

- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

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Jean-loup Gailly  
jloup@gzip.org

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---

# Python Advocacy HOWTO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: docs@python.org

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**Author** A.M. Kuchling

**Release** 0.03

### Abstract

It's usually difficult to get your management to accept open source software, and Python is no exception to this rule. This document discusses reasons to use Python, strategies for winning acceptance, facts and arguments you can use, and cases where you *shouldn't* try to use Python.

## 1 Reasons to Use Python

There are several reasons to incorporate a scripting language into your development process, and this section will discuss them, and why Python has some properties that make it a particularly good choice.

## 1.1 Programmability

Programs are often organized in a modular fashion. Lower-level operations are grouped together, and called by higher-level functions, which may in turn be used as basic operations by still further upper levels.

For example, the lowest level might define a very low-level set of functions for accessing a hash table. The next level might use hash tables to store the headers of a mail message, mapping a header name like `Date` to a value such as `Tue, 13 May 1997 20:00:54 -0400`. A yet higher level may operate on message objects, without knowing or caring that message headers are stored in a hash table, and so forth.

Often, the lowest levels do very simple things; they implement a data structure such as a binary tree or hash table, or they perform some simple computation, such as converting a date string to a number. The higher levels then contain logic connecting these primitive operations. Using the approach, the primitives can be seen as basic building blocks which are then glued together to produce the complete product.

Why is this design approach relevant to Python? Because Python is well suited to functioning as such a glue language. A common approach is to write a Python module that implements the lower level operations; for the sake of speed, the implementation might be in C, Java, or even Fortran. Once the primitives are available to Python programs, the logic underlying higher level operations is written in the form of Python code. The high-level logic is then more understandable, and easier to modify.

John Ousterhout wrote a paper that explains this idea at greater length, entitled “Scripting: Higher Level Programming for the 21st Century”. I recommend that you read this paper; see the references for the URL. Ousterhout is the inventor of the Tcl language, and therefore argues that Tcl should be used for this purpose; he only briefly refers to other languages such as Python, Perl, and Lisp/Scheme, but in reality, Ousterhout’s argument applies to scripting languages in general, since you could equally write extensions for any of the languages mentioned above.

## 1.2 Prototyping

In *The Mythical Man-Month*, Fredrick Brooks suggests the following rule when planning software projects: “Plan to throw one away; you will anyway.” Brooks is saying that the first attempt at a software design often turns out to be wrong; unless the problem is very simple or you’re an extremely good designer, you’ll find that new requirements and features become apparent once development has actually started. If these new requirements can’t be cleanly incorporated into the program’s structure, you’re presented with two unpleasant choices: hammer the new features into the program somehow, or scrap everything and write a new version of the program, taking the new features into account from the beginning.

Python provides you with a good environment for quickly developing an initial prototype. That lets you get the overall program structure and logic right, and you can fine-tune small details in the fast development cycle that Python provides. Once you’re satisfied with the GUI interface or program output, you can translate the Python code into C++, Fortran, Java, or some other compiled language.

Prototyping means you have to be careful not to use too many Python features that are hard to implement in your other language. Using `eval()`, or regular expressions, or the `pickle` module, means that you’re going to need C or Java libraries for formula evaluation, regular expressions, and serialization, for example. But it’s not hard to avoid such tricky code, and in the end the translation usually isn’t very difficult. The resulting code can be rapidly debugged, because any serious logical errors will have been removed from the prototype, leaving only more minor slip-ups in the translation to track down.

This strategy builds on the earlier discussion of programmability. Using Python as glue to connect lower-level components has obvious relevance for constructing prototype systems. In this way Python can help you with development, even if end users never come in contact with Python code at all. If the performance of the Python version is adequate and corporate politics allow it, you may not need to do a translation into C or Java, but it can still be faster to develop a prototype and then translate it, instead of attempting to produce the final version immediately.

One example of this development strategy is Microsoft Merchant Server. Version 1.0 was written in pure Python, by a company that subsequently was purchased by Microsoft. Version 2.0 began to translate the code into C++,

shipping with some C++ code and some Python code. Version 3.0 didn't contain any Python at all; all the code had been translated into C++. Even though the product doesn't contain a Python interpreter, the Python language has still served a useful purpose by speeding up development.

This is a very common use for Python. Past conference papers have also described this approach for developing high-level numerical algorithms; see David M. Beazley and Peter S. Lomdahl's paper "Feeding a Large-scale Physics Application to Python" in the references for a good example. If an algorithm's basic operations are things like "Take the inverse of this 4000x4000 matrix", and are implemented in some lower-level language, then Python has almost no additional performance cost; the extra time required for Python to evaluate an expression like `m.invert()` is dwarfed by the cost of the actual computation. It's particularly good for applications where seemingly endless tweaking is required to get things right. GUI interfaces and Web sites are prime examples.

The Python code is also shorter and faster to write (once you're familiar with Python), so it's easier to throw it away if you decide your approach was wrong; if you'd spent two weeks working on it instead of just two hours, you might waste time trying to patch up what you've got out of a natural reluctance to admit that those two weeks were wasted. Truthfully, those two weeks haven't been wasted, since you've learnt something about the problem and the technology you're using to solve it, but it's human nature to view this as a failure of some sort.

### 1.3 Simplicity and Ease of Understanding

Python is definitely *not* a toy language that's only usable for small tasks. The language features are general and powerful enough to enable it to be used for many different purposes. It's useful at the small end, for 10- or 20-line scripts, but it also scales up to larger systems that contain thousands of lines of code.

However, this expressiveness doesn't come at the cost of an obscure or tricky syntax. While Python has some dark corners that can lead to obscure code, there are relatively few such corners, and proper design can isolate their use to only a few classes or modules. It's certainly possible to write confusing code by using too many features with too little concern for clarity, but most Python code can look a lot like a slightly-formalized version of human-understandable pseudocode.

In *The New Hacker's Dictionary*, Eric S. Raymond gives the following definition for "compact":

Compact *adj.* Of a design, describes the valuable property that it can all be apprehended at once in one's head. This generally means the thing created from the design can be used with greater facility and fewer errors than an equivalent tool that is not compact. Compactness does not imply triviality or lack of power; for example, C is compact and FORTRAN is not, but C is more powerful than FORTRAN. Designs become non-compact through accreting features and cruft that don't merge cleanly into the overall design scheme (thus, some fans of Classic C maintain that ANSI C is no longer compact).

(From <http://www.catb.org/~esr/jargon/html/C/compact.html>)

In this sense of the word, Python is quite compact, because the language has just a few ideas, which are used in lots of places. Take namespaces, for example. Import a module with `import math`, and you create a new namespace called `math`. Classes are also namespaces that share many of the properties of modules, and have a few of their own; for example, you can create instances of a class. Instances? They're yet another namespace. Namespaces are currently implemented as Python dictionaries, so they have the same methods as the standard dictionary data type: `.keys()` returns all the keys, and so forth.

This simplicity arises from Python's development history. The language syntax derives from different sources; ABC, a relatively obscure teaching language, is one primary influence, and Modula-3 is another. (For more information about ABC and Modula-3, consult their respective Web sites at <http://www.cwi.nl/~steven/abc/> and <http://www.m3.org.>) Other features have come from C, Icon, Algol-68, and even Perl. Python hasn't really innovated very much, but instead has tried to keep the language small and easy to learn, building on ideas that have been tried in other languages and found useful.

Simplicity is a virtue that should not be underestimated. It lets you learn the language more quickly, and then rapidly write code – code that often works the first time you run it.

## 1.4 Java Integration

If you're working with Java, Jython (<http://www.jython.org/>) is definitely worth your attention. Jython is a re-implementation of Python in Java that compiles Python code into Java bytecodes. The resulting environment has very tight, almost seamless, integration with Java. It's trivial to access Java classes from Python, and you can write Python classes that subclass Java classes. Jython can be used for prototyping Java applications in much the same way CPython is used, and it can also be used for test suites for Java code, or embedded in a Java application to add scripting capabilities.

## 2 Arguments and Rebuttals

Let's say that you've decided upon Python as the best choice for your application. How can you convince your management, or your fellow developers, to use Python? This section lists some common arguments against using Python, and provides some possible rebuttals.

### **Python is freely available software that doesn't cost anything. How good can it be?**

Very good, indeed. These days Linux and Apache, two other pieces of open source software, are becoming more respected as alternatives to commercial software, but Python hasn't had all the publicity.

Python has been around for several years, with many users and developers. Accordingly, the interpreter has been used by many people, and has gotten most of the bugs shaken out of it. While bugs are still discovered at intervals, they're usually either quite obscure (they'd have to be, for no one to have run into them before) or they involve interfaces to external libraries. The internals of the language itself are quite stable.

Having the source code should be viewed as making the software available for peer review; people can examine the code, suggest (and implement) improvements, and track down bugs. To find out more about the idea of open source code, along with arguments and case studies supporting it, go to <http://www.opensource.org>.

### **Who's going to support it?**

Python has a sizable community of developers, and the number is still growing. The Internet community surrounding the language is an active one, and is worth being considered another one of Python's advantages. Most questions posted to the `comp.lang.python` newsgroup are quickly answered by someone.

Should you need to dig into the source code, you'll find it's clear and well-organized, so it's not very difficult to write extensions and track down bugs yourself. If you'd prefer to pay for support, there are companies and individuals who offer commercial support for Python.

### **Who uses Python for serious work?**

Lots of people; one interesting thing about Python is the surprising diversity of applications that it's been used for. People are using Python to:

- Run Web sites
- Write GUI interfaces
- Control number-crunching code on supercomputers
- Make a commercial application scriptable by embedding the Python interpreter inside it
- Process large XML data sets
- Build test suites for C or Java code

Whatever your application domain is, there's probably someone who's used Python for something similar. Yet, despite being useable for such high-end applications, Python's still simple enough to use for little jobs.

See <http://wiki.python.org/moin/OrganizationsUsingPython> for a list of some of the organizations that use Python.

## What are the restrictions on Python's use?

They're practically nonexistent. Consult *history-and-license* for the full language, but it boils down to three conditions:

- You have to leave the copyright notice on the software; if you don't include the source code in a product, you have to put the copyright notice in the supporting documentation.
- Don't claim that the institutions that have developed Python endorse your product in any way.
- If something goes wrong, you can't sue for damages. Practically all software licenses contain this condition.

Notice that you don't have to provide source code for anything that contains Python or is built with it. Also, the Python interpreter and accompanying documentation can be modified and redistributed in any way you like, and you don't have to pay anyone any licensing fees at all.

## Why should we use an obscure language like Python instead of well-known language X?

I hope this HOWTO, and the documents listed in the final section, will help convince you that Python isn't obscure, and has a healthily growing user base. One word of advice: always present Python's positive advantages, instead of concentrating on language X's failings. People want to know why a solution is good, rather than why all the other solutions are bad. So instead of attacking a competing solution on various grounds, simply show how Python's virtues can help.

## 3 Useful Resources

<http://www.pythonology.com/success> The Python Success Stories are a collection of stories from successful users of Python, with the emphasis on business and corporate users.

<http://www.tcl.tk/doc/scripting.html> John Ousterhout's white paper on scripting is a good argument for the utility of scripting languages, though naturally enough, he emphasizes Tcl, the language he developed. Most of the arguments would apply to any scripting language.

<http://www.python.org/workshops/1997-10/proceedings/beazley.html> The authors, David M. Beazley and Peter S. Lomdahl, describe their use of Python at Los Alamos National Laboratory. It's another good example of how Python can help get real work done. This quotation from the paper has been echoed by many people:

Originally developed as a large monolithic application for massively parallel processing systems, we have used Python to transform our application into a flexible, highly modular, and extremely powerful system for performing simulation, data analysis, and visualization. In addition, we describe how Python has solved a number of important problems related to the development, debugging, deployment, and maintenance of scientific software.

[http://pythonjournal.cognizor.com/pyj1/Everitt-Feit\\_interview98-V1.html](http://pythonjournal.cognizor.com/pyj1/Everitt-Feit_interview98-V1.html) This interview with Andy Feit, discussing Infoseek's use of Python, can be used to show that choosing Python didn't introduce any difficulties into a company's development process, and provided some substantial benefits.

<http://www.python.org/workshops/1997-10/proceedings/stein.ps> For the 6th Python conference, Greg Stein presented a paper that traced Python's adoption and usage at a startup called eShop, and later at Microsoft.

<http://www.opensource.org> Management may be doubtful of the reliability and usefulness of software that wasn't written commercially. This site presents arguments that show how open source software can have considerable advantages over closed-source software.

<http://www.faqs.org/docs/Linux-mini/Advocacy.html> The Linux Advocacy mini-HOWTO was the inspiration for this document, and is also well worth reading for general suggestions on winning acceptance for a new technology, such as Linux or Python. In general, you won't make much progress by simply attacking existing systems and complaining about their inadequacies; this often ends up looking like unfocused whining. It's much better to point out some of the many areas where Python is an improvement over other systems.

---

# Argparse Tutorial

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**author** Tshepang Lekhonkhobe <tshepang@gmail.com>

This tutorial is intended to be a gentle introduction to `argparse`, the recommended command-line parsing module in the Python standard library.

---

**Note:** There's two other modules that fulfill the same task, namely `getopt` (an equivalent for `getopt()` from the C language) and the deprecated `optparse`. Note also that `argparse` is based on `optparse`, and therefore very similar in terms of usage.

---

# 1 Concepts

Let's show the sort of functionality that we are going to explore in this introductory tutorial by making use of the `ls` command:

```
$ ls
cpython  devguide  prog.py  pypy  rm-unused-function.patch
$ ls pypy
ctypes_configure  demo  dotviewer  include  lib_pypy  lib-python ...
$ ls -l
total 20
drwxr-xr-x 19 wena wena 4096 Feb 18 18:51 cpython
drwxr-xr-x  4 wena wena 4096 Feb  8 12:04 devguide
-rwxr-xr-x  1 wena wena  535 Feb 19 00:05 prog.py
drwxr-xr-x 14 wena wena 4096 Feb  7 00:59 pypy
-rw-r--r--  1 wena wena  741 Feb 18 01:01 rm-unused-function.patch
$ ls --help
Usage: ls [OPTION]... [FILE]...
List information about the FILES (the current directory by default).
Sort entries alphabetically if none of -cftuvSUX nor --sort is specified.
...
```

A few concepts we can learn from the four commands:

- The `ls` command is useful when run without any options at all. It defaults to displaying the contents of the current directory.
- If we want beyond what it provides by default, we tell it a bit more. In this case, we want it to display a different directory, `pypy`. What we did is specify what is known as a positional argument. It's named so because the program should know what to do with the value, solely based on where it appears on the command line. This concept is more relevant to a command like `cp`, whose most basic usage is `cp SRC DEST`. The first position is *what you want copied*, and the second position is *where you want it copied to*.
- Now, say we want to change behaviour of the program. In our example, we display more info for each file instead of just showing the file names. The `-l` in that case is known as an optional argument.
- That's a snippet of the help text. It's very useful in that you can come across a program you have never used before, and can figure out how it works simply by reading it's help text.

## 2 The basics

Let us start with a very simple example which does (almost) nothing:

```
import argparse
parser = argparse.ArgumentParser()
parser.parse_args()
```

Following is a result of running the code:

```
$ python prog.py
$ python prog.py --help
usage: prog.py [-h]
```

optional arguments:

```
-h, --help  show this help message and exit
$ python prog.py --verbose
```

```
usage: prog.py [-h]
prog.py: error: unrecognized arguments: --verbose
$ python prog.py foo
usage: prog.py [-h]
prog.py: error: unrecognized arguments: foo
```

Here is what is happening:

- Running the script without any options results in nothing displayed to stdout. Not so useful.
- The second one starts to display the usefulness of the `argparse` module. We have done almost nothing, but already we get a nice help message.
- The `--help` option, which can also be shortened to `-h`, is the only option we get for free (i.e. no need to specify it). Specifying anything else results in an error. But even then, we do get a useful usage message, also for free.

### 3 Introducing Positional arguments

An example:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo")
args = parser.parse_args()
print args.echo
```

And running the code:

```
$ python prog.py
usage: prog.py [-h] echo
prog.py: error: the following arguments are required: echo
$ python prog.py --help
usage: prog.py [-h] echo
```

```
positional arguments:
  echo
```

```
optional arguments:
  -h, --help  show this help message and exit
$ python prog.py foo
foo
```

Here is what's happening:

- We've added the `add_argument()` method, which is what we use to specify which command-line options the program is willing to accept. In this case, I've named it `echo` so that it's in line with its function.
- Calling our program now requires us to specify an option.
- The `parse_args()` method actually returns some data from the options specified, in this case, `echo`.
- The variable is some form of 'magic' that `argparse` performs for free (i.e. no need to specify which variable that value is stored in). You will also notice that its name matches the string argument given to the method, `echo`.

Note however that, although the help display looks nice and all, it currently is not as helpful as it can be. For example we see that we got `echo` as a positional argument, but we don't know what it does, other than by guessing or by reading the source code. So, let's make it a bit more useful:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo", help="echo the string you use here")
args = parser.parse_args()
print args.echo
```

And we get:

```
$ python prog.py -h
usage: prog.py [-h] echo
```

```
positional arguments:
  echo                echo the string you use here
```

```
optional arguments:
  -h, --help          show this help message and exit
```

Now, how about doing something even more useful:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square of a given number")
args = parser.parse_args()
print args.square**2
```

Following is a result of running the code:

```
$ python prog.py 4
Traceback (most recent call last):
  File "prog.py", line 5, in <module>
    print args.square**2
TypeError: unsupported operand type(s) for **: 'str' and 'int'
```

That didn't go so well. That's because argparse treats the options we give it as strings, unless we tell it otherwise. So, let's tell argparse to treat that input as an integer:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square of a given number",
                    type=int)
args = parser.parse_args()
print args.square**2
```

Following is a result of running the code:

```
$ python prog.py 4
16
$ python prog.py four
usage: prog.py [-h] square
prog.py: error: argument square: invalid int value: 'four'
```

That went well. The program now even helpfully quits on bad illegal input before proceeding.

## 4 Introducing Optional arguments

So far we, have been playing with positional arguments. Let us have a look on how to add optional ones:

```

import argparse
parser = argparse.ArgumentParser()
parser.add_argument("--verbosity", help="increase output verbosity")
args = parser.parse_args()
if args.verbosity:
    print "verbosity turned on"

```

And the output:

```

$ python prog.py --verbosity 1
verbosity turned on
$ python prog.py
$ python prog.py --help
usage: prog.py [-h] [--verbosity VERBOSITY]

```

optional arguments:

```

-h, --help            show this help message and exit
--verbosity VERBOSITY
                    increase output verbosity

```

```

$ python prog.py --verbosity
usage: prog.py [-h] [--verbosity VERBOSITY]
prog.py: error: argument --verbosity: expected one argument

```

Here is what is happening:

- The program is written so as to display something when `--verbosity` is specified and display nothing when not.
- To show that the option is actually optional, there is no error when running the program without it. Note that by default, if an optional argument isn't used, the relevant variable, in this case `args.verbosity`, is given `None` as a value, which is the reason it fails the truth test of the `if` statement.
- The help message is a bit different.
- When using the `--verbosity` option, one must also specify some value, any value.

The above example accepts arbitrary integer values for `--verbosity`, but for our simple program, only two values are actually useful, `True` or `False`. Let's modify the code accordingly:

```

import argparse
parser = argparse.ArgumentParser()
parser.add_argument("--verbose", help="increase output verbosity",
                    action="store_true")
args = parser.parse_args()
if args.verbose:
    print "verbosity turned on"

```

And the output:

```

$ python prog.py --verbose
verbosity turned on
$ python prog.py --verbose 1
usage: prog.py [-h] [--verbose]
prog.py: error: unrecognized arguments: 1
$ python prog.py --help
usage: prog.py [-h] [--verbose]

```

optional arguments:

```
-h, --help  show this help message and exit
--verbose  increase output verbosity
```

Here is what is happening:

- The option is now more of a flag than something that requires a value. We even changed the name of the option to match that idea. Note that we now specify a new keyword, `action`, and give it the value `"store_true"`. This means that, if the option is specified, assign the value `True` to `args.verbose`. Not specifying it implies `False`.
- It complains when you specify a value, in true spirit of what flags actually are.
- Notice the different help text.

## 4.1 Short options

If you are familiar with command line usage, you will notice that I haven't yet touched on the topic of short versions of the options. It's quite simple:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("-v", "--verbose", help="increase output verbosity",
                    action="store_true")
args = parser.parse_args()
if args.verbose:
    print "verbosity turned on"
```

And here goes:

```
$ python prog.py -v
verbosity turned on
$ python prog.py --help
usage: prog.py [-h] [-v]
```

optional arguments:

```
-h, --help  show this help message and exit
-v, --verbose  increase output verbosity
```

Note that the new ability is also reflected in the help text.

## 5 Combining Positional and Optional arguments

Our program keeps growing in complexity:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbose", action="store_true",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbose:
    print "the square of {} equals {}".format(args.square, answer)
else:
    print answer
```

And now the output:

```
$ python prog.py
usage: prog.py [-h] [-v] square
prog.py: error: the following arguments are required: square
$ python prog.py 4
16
$ python prog.py 4 --verbose
the square of 4 equals 16
$ python prog.py --verbose 4
the square of 4 equals 16
```

- We've brought back a positional argument, hence the complaint.
- Note that the order does not matter.

How about we give this program of ours back the ability to have multiple verbosity values, and actually get to use them:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int,
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print "the square of {} equals {}".format(args.square, answer)
elif args.verbosity == 1:
    print "{}^2 == {}".format(args.square, answer)
else:
    print answer
```

And the output:

```
$ python prog.py 4
16
$ python prog.py 4 -v
usage: prog.py [-h] [-v VERBOSITY] square
prog.py: error: argument -v/--verbosity: expected one argument
$ python prog.py 4 -v 1
4^2 == 16
$ python prog.py 4 -v 2
the square of 4 equals 16
$ python prog.py 4 -v 3
16
```

These all look good except the last one, which exposes a bug in our program. Let's fix it by restricting the values the `--verbosity` option can accept:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int, choices=[0, 1, 2],
                    help="increase output verbosity")
args = parser.parse_args()
```

```

answer = args.square**2
if args.verbosity == 2:
    print "the square of {} equals {}".format(args.square, answer)
elif args.verbosity == 1:
    print "{}^2 == {}".format(args.square, answer)
else:
    print answer

```

And the output:

```

$ python prog.py 4 -v 3
usage: prog.py [-h] [-v {0,1,2}] square
prog.py: error: argument -v/--verbosity: invalid choice: 3 (choose from 0, 1, 2)
$ python prog.py 4 -h
usage: prog.py [-h] [-v {0,1,2}] square

```

positional arguments:

```

square          display a square of a given number

```

optional arguments:

```

-h, --help          show this help message and exit
-v {0,1,2}, --verbosity {0,1,2}
                    increase output verbosity

```

Note that the change also reflects both in the error message as well as the help string.

Now, let's use a different approach of playing with verbosity, which is pretty common. It also matches the way the CPython executable handles its own verbosity argument (check the output of `python --help`):

```

import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display the square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print "the square of {} equals {}".format(args.square, answer)
elif args.verbosity == 1:
    print "{}^2 == {}".format(args.square, answer)
else:
    print answer

```

We have introduced another action, "count", to count the number of occurrences of a specific optional arguments:

```

$ python prog.py 4
16
$ python prog.py 4 -v
4^2 == 16
$ python prog.py 4 -vv
the square of 4 equals 16
$ python prog.py 4 --verbosity --verbosity
the square of 4 equals 16
$ python prog.py 4 -v 1
usage: prog.py [-h] [-v] square
prog.py: error: unrecognized arguments: 1

```

```
$ python prog.py 4 -h
usage: prog.py [-h] [-v] square
```

positional arguments:

square                    display a square of a given number

optional arguments:

-h, --help                show this help message and exit

-v, --verbosity          increase output verbosity

```
$ python prog.py 4 -vvv
```

```
16
```

- Yes, it's now more of a flag (similar to `action="store_true"`) in the previous version of our script. That should explain the complaint.
- It also behaves similar to “store\_true” action.
- Now here's a demonstration of what the “count” action gives. You've probably seen this sort of usage before.
- And, just like the “store\_true” action, if you don't specify the `-v` flag, that flag is considered to have None value.
- As should be expected, specifying the long form of the flag, we should get the same output.
- Sadly, our help output isn't very informative on the new ability our script has acquired, but that can always be fixed by improving the documentation for our script (e.g. via the `help` keyword argument).
- That last output exposes a bug in our program.

Let's fix:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2

# bugfix: replace == with >=
if args.verbosity >= 2:
    print "the square of {} equals {}".format(args.square, answer)
elif args.verbosity >= 1:
    print "{}^2 == {}".format(args.square, answer)
else:
    print answer
```

And this is what it gives:

```
$ python prog.py 4 -vvv
```

```
the square of 4 equals 16
```

```
$ python prog.py 4 -vvvv
```

```
the square of 4 equals 16
```

```
$ python prog.py 4
```

```
Traceback (most recent call last):
```

```
File "prog.py", line 11, in <module>
```

```
    if args.verbosity >= 2:
```

```
TypeError: unorderable types: NoneType() >= int()
```

- First output went well, and fixes the bug we had before. That is, we want any value  $\geq 2$  to be as verbose as possible.
- Third output not so good.

Let's fix that bug:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count", default=0,
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity >= 2:
    print "the square of {} equals {}".format(args.square, answer)
elif args.verbosity >= 1:
    print "{}^2 == {}".format(args.square, answer)
else:
    print answer
```

We've just introduced yet another keyword, `default`. We've set it to 0 in order to make it comparable to the other int values. Remember that by default, if an optional argument isn't specified, it gets the `None` value, and that cannot be compared to an int value (hence the `TypeError` exception).

And:

```
$ python prog.py 4
16
```

You can go quite far just with what we've learned so far, and we have only scratched the surface. The `argparse` module is very powerful, and we'll explore a bit more of it before we end this tutorial.

## 6 Getting a little more advanced

What if we wanted to expand our tiny program to perform other powers, not just squares:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count", default=0)
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print "{} to the power {} equals {}".format(args.x, args.y, answer)
elif args.verbosity >= 1:
    print "{}^{} == {}".format(args.x, args.y, answer)
else:
    print answer
```

Output:

```
$ python prog.py
usage: prog.py [-h] [-v] x y
prog.py: error: the following arguments are required: x, y
```

```

$ python prog.py -h
usage: prog.py [-h] [-v] x y

positional arguments:
  x                the base
  y                the exponent

optional arguments:
  -h, --help      show this help message and exit
  -v, --verbosity
$ python prog.py 4 2 -v
4^2 == 16

```

Notice that so far we've been using verbosity level to *change* the text that gets displayed. The following example instead uses verbosity level to display *more* text instead:

```

import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count", default=0)
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print "Running '{}'.format(__file__)
if args.verbosity >= 1:
    print "{}^{} ==".format(args.x, args.y),
print answer

```

Output:

```

$ python prog.py 4 2
16
$ python prog.py 4 2 -v
4^2 == 16
$ python prog.py 4 2 -vv
Running 'prog.py'
4^2 == 16

```

## 6.1 Conflicting options

So far, we have been working with two methods of an `argparse.ArgumentParser` instance. Let's introduce a third one, `add_mutually_exclusive_group()`. It allows for us to specify options that conflict with each other. Let's also change the rest of the program make the new functionality makes more sense: we'll introduce the `--quiet` option, which will be the opposite of the `--verbose` one:

```

import argparse

parser = argparse.ArgumentParser()
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
args = parser.parse_args()
answer = args.x**args.y

```

```

if args.quiet:
    print answer
elif args.verbose:
    print "{} to the power {} equals {}".format(args.x, args.y, answer)
else:
    print "{}^{} == {}".format(args.x, args.y, answer)

```

Our program is now simpler, and we've lost some functionality for the sake of demonstration. Anyways, here's the output:

```

$ python prog.py 4 2
4^2 == 16
$ python prog.py 4 2 -q
16
$ python prog.py 4 2 -v
4 to the power 2 equals 16
$ python prog.py 4 2 -vq
usage: prog.py [-h] [-v | -q] x y
prog.py: error: argument -q/--quiet: not allowed with argument -v/--verbose
$ python prog.py 4 2 -v --quiet
usage: prog.py [-h] [-v | -q] x y
prog.py: error: argument -q/--quiet: not allowed with argument -v/--verbose

```

That should be easy to follow. I've added that last output so you can see the sort of flexibility you get, i.e. mixing long form options with short form ones.

Before we conclude, you probably want to tell your users the main purpose of your program, just in case they don't know:

```
import argparse
```

```

parser = argparse.ArgumentParser(description="calculate X to the power of Y")
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
args = parser.parse_args()
answer = args.x**args.y

```

```

if args.quiet:
    print answer
elif args.verbose:
    print "{} to the power {} equals {}".format(args.x, args.y, answer)
else:
    print "{}^{} == {}".format(args.x, args.y, answer)

```

Note that slight difference in the usage text. Note the `[-v | -q]`, which tells us that we can either use `-v` or `-q`, but not both at the same time:

```

$ python prog.py --help
usage: prog.py [-h] [-v | -q] x y

```

calculate X to the power of Y

positional arguments:

```
x          the base
y          the exponent
```

optional arguments:

```
-h, --help      show this help message and exit
-v, --verbose
-q, --quiet
```

## 7 Conclusion

The `argparse` module offers a lot more than shown here. Its docs are quite detailed and thorough, and full of examples. Having gone through this tutorial, you should easily digest them without feeling overwhelmed.

---

# Porting Extension Modules to Python 3

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**author** Benjamin Peterson

### Abstract

Although changing the C-API was not one of Python 3's objectives, the many Python-level changes made leaving Python 2's API intact impossible. In fact, some changes such as `int()` and `long()` unification are more obvious on the C level. This document endeavors to document incompatibilities and how they can be worked around.

## 1 Conditional compilation

The easiest way to compile only some code for Python 3 is to check if `PY_MAJOR_VERSION` is greater than or equal to 3.

```
#if PY_MAJOR_VERSION >= 3
#define IS_PY3K
#endif
```

API functions that are not present can be aliased to their equivalents within conditional blocks.

## 2 Changes to Object APIs

Python 3 merged together some types with similar functions while cleanly separating others.

### 2.1 str/unicode Unification

Python 3's `str()` (`PyString_*` functions in C) type is equivalent to Python 2's `unicode()` (`PyUnicode_*`). The old 8-bit string type has become `bytes()`. Python 2.6 and later provide a compatibility header, `bytesobject.h`, mapping `PyBytes` names to `PyString` ones. For best compatibility with Python 3, `PyUnicode` should be used for textual data and `PyBytes` for binary data. It's also important to remember that `PyBytes` and `PyUnicode` in Python 3 are not interchangeable like `PyString` and `PyUnicode` are in Python 2. The following example shows best practices with regards to `PyUnicode`, `PyString`, and `PyBytes`.

```
#include "stdlib.h"
#include "Python.h"
#include "bytesobject.h"

/* text example */
static PyObject *
say_hello(PyObject *self, PyObject *args) {
    PyObject *name, *result;

    if (!PyArg_ParseTuple(args, "U:say_hello", &name))
        return NULL;

    result = PyUnicode_FromFormat("Hello, %S!", name);
    return result;
}

/* just a forward */
static char * do_encode(PyObject *);

/* bytes example */
static PyObject *
encode_object(PyObject *self, PyObject *args) {
    char *encoded;
    PyObject *result, *myobj;

    if (!PyArg_ParseTuple(args, "O:encode_object", &myobj))
        return NULL;

    encoded = do_encode(myobj);
    if (encoded == NULL)
        return NULL;
    result = PyBytes_FromString(encoded);
    free(encoded);
}
```

```

    return result;
}

```

## 2.2 long/int Unification

Python 3 has only one integer type, `int()`. But it actually corresponds to Python 2's `long()` type—the `int()` type used in Python 2 was removed. In the C-API, `PyInt_*` functions are replaced by their `PyLong_*` equivalents.

The best course of action here is using the `PyInt_*` functions aliased to `PyLong_*` found in `intobject.h`. The abstract `PyNumber_*` APIs can also be used in some cases.

```

#include "Python.h"
#include "intobject.h"

static PyObject *
add_ints(PyObject *self, PyObject *args) {
    int one, two;
    PyObject *result;

    if (!PyArg_ParseTuple(args, "ii:add_ints", &one, &two))
        return NULL;

    return PyInt_FromLong(one + two);
}

```

## 3 Module initialization and state

Python 3 has a revamped extension module initialization system. (See

**PEP 3121**.) Instead of storing module state in globals, they should be stored in an interpreter specific structure. Creating modules that act correctly in both Python 2 and Python 3 is tricky. The following simple example demonstrates how.

```

#include "Python.h"

struct module_state {
    PyObject *error;
};

#if PY_MAJOR_VERSION >= 3
#define GETSTATE(m) ((struct module_state*)PyModule_GetState(m))
#else
#define GETSTATE(m) (&_state)
static struct module_state _state;
#endif

static PyObject *
error_out(PyObject *m) {
    struct module_state *st = GETSTATE(m);
    PyErr_SetString(st->error, "something bad happened");
    return NULL;
}

```

```

static PyMethodDef myextension_methods[] = {
    {"error_out", (PyCFunction)error_out, METH_NOARGS, NULL},
    {NULL, NULL}
};

#if PY_MAJOR_VERSION >= 3

static int myextension_traverse(PyObject *m, visitproc visit, void *arg) {
    Py_VISIT(GETSTATE(m)->error);
    return 0;
}

static int myextension_clear(PyObject *m) {
    Py_CLEAR(GETSTATE(m)->error);
    return 0;
}

static struct PyModuleDef moduledef = {
    PyModuleDef_HEAD_INIT,
    "myextension",
    NULL,
    sizeof(struct module_state),
    myextension_methods,
    NULL,
    myextension_traverse,
    myextension_clear,
    NULL
};

#define INITERROR return NULL

PyObject *
PyInit_myextension(void)

#else
#define INITERROR return

void
initmyextension(void)
#endif
{
    #if PY_MAJOR_VERSION >= 3
        PyObject *module = PyModule_Create(&moduledef);
    #else
        PyObject *module = Py_InitModule("myextension", myextension_methods);
    #endif

    if (module == NULL)
        INITERROR;
    struct module_state *st = GETSTATE(module);

    st->error = PyErr_NewException("myextension.Error", NULL, NULL);
    if (st->error == NULL) {

```

```

        Py_DECREF(module);
        INITERROR;
    }

    #if PY_MAJOR_VERSION >= 3
        return module;
    #endif
}

```

## 4 CObject replaced with Capsule

The Capsule object was introduced in Python 3.1 and 2.7 to replace CObject. CObjects were useful, but the CObject API was problematic: it didn't permit distinguishing between valid CObjects, which allowed mismatched CObjects to crash the interpreter, and some of its APIs relied on undefined behavior in C. (For further reading on the rationale behind Capsules, please see [issue 5630](#).)

If you're currently using CObjects, and you want to migrate to 3.1 or newer, you'll need to switch to Capsules. CObject was deprecated in 3.1 and 2.7 and completely removed in Python 3.2. If you only support 2.7, or 3.1 and above, you can simply switch to Capsule. If you need to support Python 3.0, or versions of Python earlier than 2.7, you'll have to support both CObjects and Capsules. (Note that Python 3.0 is no longer supported, and it is not recommended for production use.)

The following example header file `capsulethunk.h` may solve the problem for you. Simply write your code against the Capsule API and include this header file after `Python.h`. Your code will automatically use Capsules in versions of Python with Capsules, and switch to CObjects when Capsules are unavailable.

`capsulethunk.h` simulates Capsules using CObjects. However, CObject provides no place to store the capsule's "name". As a result the simulated Capsule objects created by `capsulethunk.h` behave slightly differently from real Capsules. Specifically:

- The name parameter passed in to `PyCapsule_New()` is ignored.
- The name parameter passed in to `PyCapsule_IsValid()` and `PyCapsule_GetPointer()` is ignored, and no error checking of the name is performed.
- `PyCapsule_GetName()` always returns NULL.
- `PyCapsule_SetName()` always throws an exception and returns failure. (Since there's no way to store a name in a CObject, noisy failure of `PyCapsule_SetName()` was deemed preferable to silent failure here. If this is inconvenient, feel free to modify your local copy as you see fit.)

You can find `capsulethunk.h` in the Python source distribution as `Doc/includes/capsulethunk.h`. We also include it here for your convenience:

```

#ifndef __CAPSULETHUNK_H
#define __CAPSULETHUNK_H

#if ( (PY_VERSION_HEX < 0x02070000) \
      || ((PY_VERSION_HEX >= 0x03000000) \
          && (PY_VERSION_HEX < 0x03010000)) )

#define __PyCapsule_GetField(capsule, field, default_value) \
    ( PyCapsule_CheckExact(capsule) \
      ? ((PyCObject *)capsule)->field) \
      : (default_value) \
    ) \

```

```

#define __PyCapsule_SetField(capsule, field, value) \
    ( PyCapsule_CheckExact(capsule) \
      ? ((PyObject *)capsule)->field = value, 1 \
      : 0 \
    ) \

#define PyCapsule_Type PyObject_Type

#define PyCapsule_CheckExact(capsule) (PyObject_Check(capsule))
#define PyCapsule_IsValid(capsule, name) (PyObject_Check(capsule))

#define PyCapsule_New(pointer, name, destructor) \
    (PyObject_FromVoidPtr(pointer, destructor))

#define PyCapsule_GetPointer(capsule, name) \
    (PyObject_AsVoidPtr(capsule))

/* Don't call PyObject_SetPointer here, it fails if there's a destructor */
#define PyCapsule_SetPointer(capsule, pointer) \
    __PyCapsule_SetField(capsule, cobject, pointer)

#define PyCapsule_GetDestructor(capsule) \
    __PyCapsule_GetField(capsule, destructor)

#define PyCapsule_SetDestructor(capsule, dtor) \
    __PyCapsule_SetField(capsule, destructor, dtor)

/*
 * Sorry, there's simply no place
 * to store a Capsule "name" in a CObject.
 */
#define PyCapsule_GetName(capsule) NULL

static int
PyCapsule_SetName(PyObject *capsule, const char *unused)
{
    unused = unused;
    PyErr_SetString(PyExc_NotImplementedError,
        "can't use PyCapsule_SetName with CObjects");
    return 1;
}

#define PyCapsule_GetContext(capsule) \
    __PyCapsule_GetField(capsule, descr)

#define PyCapsule_SetContext(capsule, context) \
    __PyCapsule_SetField(capsule, descr, context)

```

```

static void *
PyCapsule_Import(const char *name, int no_block)
{
    PyObject *object = NULL;
    void *return_value = NULL;
    char *trace;
    size_t name_length = (strlen(name) + 1) * sizeof(char);
    char *name_dup = (char *)PyMem_MALLOC(name_length);

    if (!name_dup) {
        return NULL;
    }

    memcpy(name_dup, name, name_length);

    trace = name_dup;
    while (trace) {
        char *dot = strchr(trace, '.');
        if (dot) {
            *dot++ = '\\0';
        }

        if (object == NULL) {
            if (no_block) {
                object = PyImport_ImportModuleNoBlock(trace);
            } else {
                object = PyImport_ImportModule(trace);
                if (!object) {
                    PyErr_Format(PyExc_ImportError,
                        "PyCapsule_Import could not "
                        "import module \"%s\"", trace);
                }
            }
        } else {
            PyObject *object2 = PyObject_GetAttrString(object, trace);
            Py_DECREF(object);
            object = object2;
        }
        if (!object) {
            goto EXIT;
        }

        trace = dot;
    }

    if (PyCObject_Check(object)) {
        PyCObject *cobject = (PyCObject *)object;
        return_value = cobject->cobject;
    } else {
        PyErr_Format(PyExc_AttributeError,
            "PyCapsule_Import \"%s\" is not valid",
            name);
    }
}

```

```
    }  
  
EXIT:  
    Py_XDECREF(object);  
    if (name_dup) {  
        PyMem_FREE(name_dup);  
    }  
    return return_value;  
}  
  
#endif /* #if PY_VERSION_HEX < 0x02070000 */  
  
#endif /* __CAPSULETHUNK_H */
```

## 5 Other options

If you are writing a new extension module, you might consider [Cython](#). It translates a Python-like language to C. The extension modules it creates are compatible with Python 3 and Python 2.

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# Curses Programming with Python

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: docs@python.org

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**Author** A.M. Kuchling, Eric S. Raymond

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### Abstract

This document describes how to write text-mode programs with Python 2.x, using the `curses` extension module to control the display.

## 1 What is curses?

The `curses` library supplies a terminal-independent screen-painting and keyboard-handling facility for text-based terminals; such terminals include VT100s, the Linux console, and the simulated terminal provided by X11 programs such as `xterm` and `rxvt`. Display terminals support various control codes to perform common operations such as moving

the cursor, scrolling the screen, and erasing areas. Different terminals use widely differing codes, and often have their own minor quirks.

In a world of X displays, one might ask “why bother”? It’s true that character-cell display terminals are an obsolete technology, but there are niches in which being able to do fancy things with them are still valuable. One is on small-footprint or embedded Unixes that don’t carry an X server. Another is for tools like OS installers and kernel configurators that may have to run before X is available.

The curses library hides all the details of different terminals, and provides the programmer with an abstraction of a display, containing multiple non-overlapping windows. The contents of a window can be changed in various ways—adding text, erasing it, changing its appearance—and the curses library will automagically figure out what control codes need to be sent to the terminal to produce the right output.

The curses library was originally written for BSD Unix; the later System V versions of Unix from AT&T added many enhancements and new functions. BSD curses is no longer maintained, having been replaced by ncurses, which is an open-source implementation of the AT&T interface. If you’re using an open-source Unix such as Linux or FreeBSD, your system almost certainly uses ncurses. Since most current commercial Unix versions are based on System V code, all the functions described here will probably be available. The older versions of curses carried by some proprietary Unixes may not support everything, though.

No one has made a Windows port of the curses module. On a Windows platform, try the Console module written by Fredrik Lundh. The Console module provides cursor-addressable text output, plus full support for mouse and keyboard input, and is available from <http://effbot.org/zone/console-index.htm>.

## 1.1 The Python curses module

Thy Python module is a fairly simple wrapper over the C functions provided by curses; if you’re already familiar with curses programming in C, it’s really easy to transfer that knowledge to Python. The biggest difference is that the Python interface makes things simpler, by merging different C functions such as `addstr()`, `mvaddstr()`, `mvwaddstr()`, into a single `addstr()` method. You’ll see this covered in more detail later.

This HOWTO is simply an introduction to writing text-mode programs with curses and Python. It doesn’t attempt to be a complete guide to the curses API; for that, see the Python library guide’s section on ncurses, and the C manual pages for ncurses. It will, however, give you the basic ideas.

## 2 Starting and ending a curses application

Before doing anything, curses must be initialized. This is done by calling the `initscr()` function, which will determine the terminal type, send any required setup codes to the terminal, and create various internal data structures. If successful, `initscr()` returns a window object representing the entire screen; this is usually called `stdscr`, after the name of the corresponding C variable.

```
import curses
stdscr = curses.initscr()
```

Usually curses applications turn off automatic echoing of keys to the screen, in order to be able to read keys and only display them under certain circumstances. This requires calling the `noecho()` function.

```
curses.noecho()
```

Applications will also commonly need to react to keys instantly, without requiring the Enter key to be pressed; this is called cbreak mode, as opposed to the usual buffered input mode.

```
curses.cbreak()
```

Terminals usually return special keys, such as the cursor keys or navigation keys such as Page Up and Home, as a multibyte escape sequence. While you could write your application to expect such sequences and process them

accordingly, curses can do it for you, returning a special value such as `curses.KEY_LEFT`. To get curses to do the job, you'll have to enable keypad mode.

```
stdscr.keypad(1)
```

Terminating a curses application is much easier than starting one. You'll need to call

```
curses.nocbreak(); stdscr.keypad(0); curses.echo()
```

to reverse the curses-friendly terminal settings. Then call the `endwin()` function to restore the terminal to its original operating mode.

```
curses.endwin()
```

A common problem when debugging a curses application is to get your terminal messed up when the application dies without restoring the terminal to its previous state. In Python this commonly happens when your code is buggy and raises an uncaught exception. Keys are no longer echoed to the screen when you type them, for example, which makes using the shell difficult.

In Python you can avoid these complications and make debugging much easier by importing the module `curses.wrapper`. It supplies a `wrapper()` function that takes a callable. It does the initializations described above, and also initializes colors if color support is present. It then runs your provided callable and finally deinitializes appropriately. The callable is called inside a try-catch clause which catches exceptions, performs curses deinitialization, and then passes the exception upwards. Thus, your terminal won't be left in a funny state on exception.

### 3 Windows and Pads

Windows are the basic abstraction in curses. A window object represents a rectangular area of the screen, and supports various methods to display text, erase it, allow the user to input strings, and so forth.

The `stdscr` object returned by the `initscr()` function is a window object that covers the entire screen. Many programs may need only this single window, but you might wish to divide the screen into smaller windows, in order to redraw or clear them separately. The `newwin()` function creates a new window of a given size, returning the new window object.

```
begin_x = 20 ; begin_y = 7
height = 5 ; width = 40
win = curses.newwin(height, width, begin_y, begin_x)
```

A word about the coordinate system used in curses: coordinates are always passed in the order  $y,x$ , and the top-left corner of a window is coordinate (0,0). This breaks a common convention for handling coordinates, where the  $x$  coordinate usually comes first. This is an unfortunate difference from most other computer applications, but it's been part of curses since it was first written, and it's too late to change things now.

When you call a method to display or erase text, the effect doesn't immediately show up on the display. This is because curses was originally written with slow 300-baud terminal connections in mind; with these terminals, minimizing the time required to redraw the screen is very important. This lets curses accumulate changes to the screen, and display them in the most efficient manner. For example, if your program displays some characters in a window, and then clears the window, there's no need to send the original characters because they'd never be visible.

Accordingly, curses requires that you explicitly tell it to redraw windows, using the `refresh()` method of window objects. In practice, this doesn't really complicate programming with curses much. Most programs go into a flurry of activity, and then pause waiting for a keypress or some other action on the part of the user. All you have to do is to be sure that the screen has been redrawn before pausing to wait for user input, by simply calling `stdscr.refresh()` or the `refresh()` method of some other relevant window.

A pad is a special case of a window; it can be larger than the actual display screen, and only a portion of it displayed at a time. Creating a pad simply requires the pad's height and width, while refreshing a pad requires giving the coordinates of the on-screen area where a subsection of the pad will be displayed.

```

pad = curses.newpad(100, 100)
# These loops fill the pad with letters; this is
# explained in the next section
for y in range(0, 100):
    for x in range(0, 100):
        try: pad.addch(y,x, ord('a') + (x*x+y*y) % 26 )
        except curses.error: pass

# Displays a section of the pad in the middle of the screen
pad.refresh( 0,0, 5,5, 20,75)

```

The `refresh()` call displays a section of the pad in the rectangle extending from coordinate (5,5) to coordinate (20,75) on the screen; the upper left corner of the displayed section is coordinate (0,0) on the pad. Beyond that difference, pads are exactly like ordinary windows and support the same methods.

If you have multiple windows and pads on screen there is a more efficient way to go, which will prevent annoying screen flicker at refresh time. Use the `noutrefresh()` method of each window to update the data structure representing the desired state of the screen; then change the physical screen to match the desired state in one go with the function `doupdate()`. The normal `refresh()` method calls `doupdate()` as its last act.

## 4 Displaying Text

From a C programmer's point of view, curses may sometimes look like a twisty maze of functions, all subtly different. For example, `addstr()` displays a string at the current cursor location in the `stdscr` window, while `mvaddstr()` moves to a given `y,x` coordinate first before displaying the string. `waddstr()` is just like `addstr()`, but allows specifying a window to use, instead of using `stdscr` by default. `mvwaddstr()` follows similarly.

Fortunately the Python interface hides all these details; `stdscr` is a window object like any other, and methods like `addstr()` accept multiple argument forms. Usually there are four different forms.

Form	Description
<code>str</code> or <code>ch</code>	Display the string <code>str</code> or character <code>ch</code> at the current position
<code>str</code> or <code>ch</code> , <code>attr</code>	Display the string <code>str</code> or character <code>ch</code> , using attribute <code>attr</code> at the current position
<code>y, x</code> , <code>str</code> or <code>ch</code>	Move to position <code>y,x</code> within the window, and display <code>str</code> or <code>ch</code>
<code>y, x</code> , <code>str</code> or <code>ch</code> , <code>attr</code>	Move to position <code>y,x</code> within the window, and display <code>str</code> or <code>ch</code> , using attribute <code>attr</code>

Attributes allow displaying text in highlighted forms, such as in boldface, underline, reverse code, or in color. They'll be explained in more detail in the next subsection.

The `addstr()` function takes a Python string as the value to be displayed, while the `addch()` functions take a character, which can be either a Python string of length 1 or an integer. If it's a string, you're limited to displaying characters between 0 and 255. SVr4 curses provides constants for extension characters; these constants are integers greater than 255. For example, `ACS_PLMINUS` is a +/- symbol, and `ACS_ULCORNER` is the upper left corner of a box (handy for drawing borders).

Windows remember where the cursor was left after the last operation, so if you leave out the `y,x` coordinates, the string or character will be displayed wherever the last operation left off. You can also move the cursor with the `move(y, x)` method. Because some terminals always display a flashing cursor, you may want to ensure that the cursor is positioned in some location where it won't be distracting; it can be confusing to have the cursor blinking at some apparently random location.

If your application doesn't need a blinking cursor at all, you can call `curs_set(0)` to make it invisible. Equivalently, and for compatibility with older curses versions, there's a `leaveok(bool)` function. When `bool` is true, the curses library will attempt to suppress the flashing cursor, and you won't need to worry about leaving it in odd locations.

## 4.1 Attributes and Color

Characters can be displayed in different ways. Status lines in a text-based application are commonly shown in reverse video; a text viewer may need to highlight certain words. `curses` supports this by allowing you to specify an attribute for each cell on the screen.

An attribute is an integer, each bit representing a different attribute. You can try to display text with multiple attribute bits set, but `curses` doesn't guarantee that all the possible combinations are available, or that they're all visually distinct. That depends on the ability of the terminal being used, so it's safest to stick to the most commonly available attributes, listed here.

Attribute	Description
<code>A_BLINK</code>	Blinking text
<code>A_BOLD</code>	Extra bright or bold text
<code>A_DIM</code>	Half bright text
<code>A_REVERSE</code>	Reverse-video text
<code>A_STANDOUT</code>	The best highlighting mode available
<code>A_UNDERLINE</code>	Underlined text

So, to display a reverse-video status line on the top line of the screen, you could code:

```
stdscr.addstr(0, 0, "Current mode: Typing mode",
              curses.A_REVERSE)
stdscr.refresh()
```

The `curses` library also supports color on those terminals that provide it. The most common such terminal is probably the Linux console, followed by color `xterms`.

To use color, you must call the `start_color()` function soon after calling `initscr()`, to initialize the default color set (the `curses.wrapper.wrapper()` function does this automatically). Once that's done, the `has_colors()` function returns `TRUE` if the terminal in use can actually display color. (Note: `curses` uses the American spelling 'color', instead of the Canadian/British spelling 'colour'. If you're used to the British spelling, you'll have to resign yourself to misspelling it for the sake of these functions.)

The `curses` library maintains a finite number of color pairs, containing a foreground (or text) color and a background color. You can get the attribute value corresponding to a color pair with the `color_pair()` function; this can be bitwise-OR'ed with other attributes such as `A_REVERSE`, but again, such combinations are not guaranteed to work on all terminals.

An example, which displays a line of text using color pair 1:

```
stdscr.addstr("Pretty text", curses.color_pair(1) )
stdscr.refresh()
```

As I said before, a color pair consists of a foreground and background color. `start_color()` initializes 8 basic colors when it activates color mode. They are: 0:black, 1:red, 2:green, 3:yellow, 4:blue, 5:magenta, 6:cyan, and 7:white. The `curses` module defines named constants for each of these colors: `curses.COLOR_BLACK`, `curses.COLOR_RED`, and so forth.

The `init_pair(n, f, b)` function changes the definition of color pair *n*, to foreground color *f* and background color *b*. Color pair 0 is hard-wired to white on black, and cannot be changed.

Let's put all this together. To change color 1 to red text on a white background, you would call:

```
curses.init_pair(1, curses.COLOR_RED, curses.COLOR_WHITE)
```

When you change a color pair, any text already displayed using that color pair will change to the new colors. You can also display new text in this color with:

```
stdscr.addstr(0,0, "RED ALERT!", curses.color_pair(1) )
```

Very fancy terminals can change the definitions of the actual colors to a given RGB value. This lets you change color 1, which is usually red, to purple or blue or any other color you like. Unfortunately, the Linux console doesn't support this, so I'm unable to try it out, and can't provide any examples. You can check if your terminal can do this by calling `can_change_color()`, which returns `TRUE` if the capability is there. If you're lucky enough to have such a talented terminal, consult your system's man pages for more information.

## 5 User Input

The `curses` library itself offers only very simple input mechanisms. Python's support adds a text-input widget that makes up some of the lack.

The most common way to get input to a window is to use its `getch()` method. `getch()` pauses and waits for the user to hit a key, displaying it if `echo()` has been called earlier. You can optionally specify a coordinate to which the cursor should be moved before pausing.

It's possible to change this behavior with the method `nodelay()`. After `nodelay(1)`, `getch()` for the window becomes non-blocking and returns `curses.ERR` (a value of -1) when no input is ready. There's also a `halfdelay()` function, which can be used to (in effect) set a timer on each `getch()`; if no input becomes available within a specified delay (measured in tenths of a second), `curses` raises an exception.

The `getch()` method returns an integer; if it's between 0 and 255, it represents the ASCII code of the key pressed. Values greater than 255 are special keys such as Page Up, Home, or the cursor keys. You can compare the value returned to constants such as `curses.KEY_PPAGE`, `curses.KEY_HOME`, or `curses.KEY_LEFT`. Usually the main loop of your program will look something like this:

```
while 1:
    c = stdscr.getch()
    if c == ord('p'): PrintDocument()
    elif c == ord('q'): break # Exit the while()
    elif c == curses.KEY_HOME: x = y = 0
```

The `curses.ascii` module supplies ASCII class membership functions that take either integer or 1-character-string arguments; these may be useful in writing more readable tests for your command interpreters. It also supplies conversion functions that take either integer or 1-character-string arguments and return the same type. For example, `curses.ascii.ctrl()` returns the control character corresponding to its argument.

There's also a method to retrieve an entire string, `getstr()`. It isn't used very often, because its functionality is quite limited; the only editing keys available are the backspace key and the Enter key, which terminates the string. It can optionally be limited to a fixed number of characters.

```
curses.echo() # Enable echoing of characters

# Get a 15-character string, with the cursor on the top line
s = stdscr.getstr(0, 0, 15)
```

The Python `curses.textpad` module supplies something better. With it, you can turn a window into a text box that supports an Emacs-like set of keybindings. Various methods of `Textbox` class support editing with input validation and gathering the edit results either with or without trailing spaces. See the library documentation on `curses.textpad` for the details.

## 6 For More Information

This HOWTO didn't cover some advanced topics, such as screen-scraping or capturing mouse events from an `xterm` instance. But the Python library page for the `curses` modules is now pretty complete. You should browse it next.

If you're in doubt about the detailed behavior of any of the ncurses entry points, consult the manual pages for your curses implementation, whether it's ncurses or a proprietary Unix vendor's. The manual pages will document any quirks, and provide complete lists of all the functions, attributes, and ACS\_\* characters available to you.

Because the curses API is so large, some functions aren't supported in the Python interface, not because they're difficult to implement, but because no one has needed them yet. Feel free to add them and then submit a patch. Also, we don't yet have support for the menu library associated with ncurses; feel free to add that.

If you write an interesting little program, feel free to contribute it as another demo. We can always use more of them!

The ncurses FAQ: <http://invisible-island.net/ncurses/ncurses.faq.html>

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# Descriptor HowTo Guide

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Raymond Hettinger

**Contact** <python at rcn dot com>

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## 1 Abstract

Defines descriptors, summarizes the protocol, and shows how descriptors are called. Examines a custom descriptor and several built-in python descriptors including functions, properties, static methods, and class methods. Shows how each works by giving a pure Python equivalent and a sample application.

Learning about descriptors not only provides access to a larger toolset, it creates a deeper understanding of how Python works and an appreciation for the elegance of its design.

## 2 Definition and Introduction

In general, a descriptor is an object attribute with “binding behavior”, one whose attribute access has been overridden by methods in the descriptor protocol. Those methods are `__get__()`, `__set__()`, and `__delete__()`. If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object’s dictionary. For instance, `a.x` has a lookup chain starting with `a.__dict__['x']`, then `type(a).__dict__['x']`, and continuing through the base classes of `type(a)` excluding metaclasses. If the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined. Note that descriptors are only invoked for new style objects or classes (a class is new style if it inherits from `object` or `type`).

Descriptors are a powerful, general purpose protocol. They are the mechanism behind properties, methods, static methods, class methods, and `super()`. They are used throughout Python itself to implement the new style classes introduced in version 2.2. Descriptors simplify the underlying C-code and offer a flexible set of new tools for everyday Python programs.

## 3 Descriptor Protocol

```
descr.__get__(self, obj, type=None) --> value
```

```
descr.__set__(self, obj, value) --> None
```

```
descr.__delete__(self, obj) --> None
```

That is all there is to it. Define any of these methods and an object is considered a descriptor and can override default behavior upon being looked up as an attribute.

If an object defines both `__get__()` and `__set__()`, it is considered a data descriptor. Descriptors that only define `__get__()` are called non-data descriptors (they are typically used for methods but other uses are possible).

Data and non-data descriptors differ in how overrides are calculated with respect to entries in an instance's dictionary. If an instance's dictionary has an entry with the same name as a data descriptor, the data descriptor takes precedence. If an instance's dictionary has an entry with the same name as a non-data descriptor, the dictionary entry takes precedence.

To make a read-only data descriptor, define both `__get__()` and `__set__()` with the `__set__()` raising an `AttributeError` when called. Defining the `__set__()` method with an exception raising placeholder is enough to make it a data descriptor.

## 4 Invoking Descriptors

A descriptor can be called directly by its method name. For example, `d.__get__(obj)`.

Alternatively, it is more common for a descriptor to be invoked automatically upon attribute access. For example, `obj.d` looks up `d` in the dictionary of `obj`. If `d` defines the method `__get__()`, then `d.__get__(obj)` is invoked according to the precedence rules listed below.

The details of invocation depend on whether `obj` is an object or a class. Either way, descriptors only work for new style objects and classes. A class is new style if it is a subclass of `object`.

For objects, the machinery is in `object.__getattr__()` which transforms `b.x` into `type(b).__dict__['x'].__get__(b, type(b))`. The implementation works through a precedence chain that gives data descriptors priority over instance variables, instance variables priority over non-data descriptors, and assigns lowest priority to `__getattr__()` if provided. The full C implementation can be found in `PyObject_GenericGetAttr()` in `Objects/object.c`.

For classes, the machinery is in `type.__getattr__()` which transforms `B.x` into `B.__dict__['x'].__get__(None, B)`. In pure Python, it looks like:

```
def __getattr__(self, key):
    "Emulate type_getattro() in Objects/typeobject.c"
    v = object.__getattr__(self, key)
    if hasattr(v, '__get__'):
        return v.__get__(None, self)
    return v
```

The important points to remember are:

- descriptors are invoked by the `__getattr__()` method
- overriding `__getattr__()` prevents automatic descriptor calls
- `__getattr__()` is only available with new style classes and objects
- `object.__getattr__()` and `type.__getattr__()` make different calls to `__get__()`.
- data descriptors always override instance dictionaries.
- non-data descriptors may be overridden by instance dictionaries.

The object returned by `super()` also has a custom `__getattr__()` method for invoking descriptors. The call `super(B, obj).m()` searches `obj.__class__.__mro__` for the base class `A` immediately following `B` and then returns `A.__dict__['m'].__get__(obj, A)`. If not a descriptor, `m` is returned unchanged. If not in the dictionary, `m` reverts to a search using `object.__getattr__()`.

Note, in Python 2.2, `super(B, obj).m()` would only invoke `__get__()` if `m` was a data descriptor. In Python 2.3, non-data descriptors also get invoked unless an old-style class is involved. The implementation details are in `super_getattro()` in `Objects/typeobject.c` and a pure Python equivalent can be found in [Guido's Tutorial](#).

The details above show that the mechanism for descriptors is embedded in the `__getattribute__()` methods for `object`, `type`, and `super()`. Classes inherit this machinery when they derive from `object` or if they have a meta-class providing similar functionality. Likewise, classes can turn-off descriptor invocation by overriding `__getattribute__()`.

## 5 Descriptor Example

The following code creates a class whose objects are data descriptors which print a message for each get or set. Overriding `__getattribute__()` is alternate approach that could do this for every attribute. However, this descriptor is useful for monitoring just a few chosen attributes:

```
class RevealAccess(object):
    """A data descriptor that sets and returns values
       normally and prints a message logging their access.
       """

    def __init__(self, initval=None, name='var'):
        self.val = initval
        self.name = name

    def __get__(self, obj, objtype):
        print 'Retrieving', self.name
        return self.val

    def __set__(self, obj, val):
        print 'Updating' , self.name
        self.val = val

>>> class MyClass(object):
      x = RevealAccess(10, 'var "x"')
      y = 5
```

```
>>> m = MyClass()
>>> m.x
Retrieving var "x"
10
>>> m.x = 20
Updating var "x"
>>> m.x
Retrieving var "x"
20
>>> m.y
5
```

The protocol is simple and offers exciting possibilities. Several use cases are so common that they have been packaged into individual function calls. Properties, bound and unbound methods, static methods, and class methods are all based on the descriptor protocol.

## 6 Properties

Calling `property()` is a succinct way of building a data descriptor that triggers function calls upon access to an attribute. Its signature is:

property(fget=None, fset=None, fdel=None, doc=None) -> property attribute

The documentation shows a typical use to define a managed attribute x:

```
class C(object):
    def getx(self): return self.__x
    def setx(self, value): self.__x = value
    def delx(self): del self.__x
    x = property(getx, setx, delx, "I'm the 'x' property.")
```

To see how property() is implemented in terms of the descriptor protocol, here is a pure Python equivalent:

```
class Property(object):
    "Emulate PyProperty_Type() in Objects/descrobject.c"

    def __init__(self, fget=None, fset=None, fdel=None, doc=None):
        self.fget = fget
        self.fset = fset
        self.fdel = fdel
        self.__doc__ = doc

    def __get__(self, obj, objtype=None):
        if obj is None:
            return self
        if self.fget is None:
            raise AttributeError, "unreadable attribute"
        return self.fget(obj)

    def __set__(self, obj, value):
        if self.fset is None:
            raise AttributeError, "can't set attribute"
        self.fset(obj, value)

    def __delete__(self, obj):
        if self.fdel is None:
            raise AttributeError, "can't delete attribute"
        self.fdel(obj)
```

The property() builtin helps whenever a user interface has granted attribute access and then subsequent changes require the intervention of a method.

For instance, a spreadsheet class may grant access to a cell value through Cell('b10').value. Subsequent improvements to the program require the cell to be recalculated on every access; however, the programmer does not want to affect existing client code accessing the attribute directly. The solution is to wrap access to the value attribute in a property data descriptor:

```
class Cell(object):
    . . .
    def getvalue(self, obj):
        "Recalculate cell before returning value"
        self.recalc()
        return obj._value
    value = property(getvalue)
```

## 7 Functions and Methods

Python's object oriented features are built upon a function based environment. Using non-data descriptors, the two are merged seamlessly.

Class dictionaries store methods as functions. In a class definition, methods are written using `def` and `lambda`, the usual tools for creating functions. The only difference from regular functions is that the first argument is reserved for the object instance. By Python convention, the instance reference is called *self* but may be called *this* or any other variable name.

To support method calls, functions include the `__get__()` method for binding methods during attribute access. This means that all functions are non-data descriptors which return bound or unbound methods depending whether they are invoked from an object or a class. In pure python, it works like this:

```
class Function(object):
    . . .
    def __get__(self, obj, objtype=None):
        "Simulate func_descr_get() in Objects/funcobject.c"
        return types.MethodType(self, obj, objtype)
```

Running the interpreter shows how the function descriptor works in practice:

```
>>> class D(object):
      def f(self, x):
          return x

>>> d = D()
>>> D.__dict__['f'] # Stored internally as a function
<function f at 0x00C45070>
>>> D.f           # Get from a class becomes an unbound method
<unbound method D.f>
>>> d.f           # Get from an instance becomes a bound method
<bound method D.f of <__main__.D object at 0x00B18C90>>
```

The output suggests that bound and unbound methods are two different types. While they could have been implemented that way, the actual C implementation of `PyMethod_Type` in `Objects/classobject.c` is a single object with two different representations depending on whether the `im_self` field is set or is `NULL` (the C equivalent of `None`).

Likewise, the effects of calling a method object depend on the `im_self` field. If set (meaning bound), the original function (stored in the `im_func` field) is called as expected with the first argument set to the instance. If unbound, all of the arguments are passed unchanged to the original function. The actual C implementation of `instancemethod_call()` is only slightly more complex in that it includes some type checking.

## 8 Static Methods and Class Methods

Non-data descriptors provide a simple mechanism for variations on the usual patterns of binding functions into methods.

To recap, functions have a `__get__()` method so that they can be converted to a method when accessed as attributes. The non-data descriptor transforms a `obj.f(*args)` call into `f(obj, *args)`. Calling `klass.f(*args)` becomes `f(*args)`.

This chart summarizes the binding and its two most useful variants:

Transformation	Called from an Object	Called from a Class
function	f(obj, *args)	f(*args)
staticmethod	f(*args)	f(*args)
classmethod	f(type(obj), *args)	f(klass, *args)

Static methods return the underlying function without changes. Calling either `c.f` or `C.f` is the equivalent of a direct lookup into `object.__getattr__ (c, "f")` or `object.__getattr__ (C, "f")`. As a result, the function becomes identically accessible from either an object or a class.

Good candidates for static methods are methods that do not reference the `self` variable.

For instance, a statistics package may include a container class for experimental data. The class provides normal methods for computing the average, mean, median, and other descriptive statistics that depend on the data. However, there may be useful functions which are conceptually related but do not depend on the data. For instance, `erf(x)` is handy conversion routine that comes up in statistical work but does not directly depend on a particular dataset. It can be called either from an object or the class: `s.erf(1.5) --> .9332` or `Sample.erf(1.5) --> .9332`.

Since static methods return the underlying function with no changes, the example calls are unexciting:

```
>>> class E(object):
    def f(x):
        print x
    f = staticmethod(f)

>>> print E.f(3)
3
>>> print E().f(3)
3
```

Using the non-data descriptor protocol, a pure Python version of `staticmethod()` would look like this:

```
class StaticMethod(object):
    "Emulate PyStaticMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, objtype=None):
        return self.f
```

Unlike static methods, class methods prepend the class reference to the argument list before calling the function. This format is the same for whether the caller is an object or a class:

```
>>> class E(object):
    def f(klass, x):
        return klass.__name__, x
    f = classmethod(f)

>>> print E.f(3)
('E', 3)
>>> print E().f(3)
('E', 3)
```

This behavior is useful whenever the function only needs to have a class reference and does not care about any underlying data. One use for class methods is to create alternate class constructors. In Python 2.3, the `classmethod` dict.`fromkeys()` creates a new dictionary from a list of keys. The pure Python equivalent is:

```
class Dict:
    . . .
```

```

def fromkeys(klass, iterable, value=None):
    "Emulate dict_fromkeys() in Objects/dictobject.c"
    d = klass()
    for key in iterable:
        d[key] = value
    return d
fromkeys = classmethod(fromkeys)

```

Now a new dictionary of unique keys can be constructed like this:

```

>>> Dict.fromkeys('abracadabra')
{'a': None, 'r': None, 'b': None, 'c': None, 'd': None}

```

Using the non-data descriptor protocol, a pure Python version of `classmethod()` would look like this:

```

class ClassMethod(object):
    "Emulate PyClassMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, klass=None):
        if klass is None:
            klass = type(obj)
        def newfunc(*args):
            return self.f(klass, *args)
        return newfunc

```

---

# Idioms and Anti-Idioms in Python

Release 2.7.3

Guido van Rossum  
Fred L. Drake, Jr., editor

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Python Software Foundation  
Email: docs@python.org

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**Author** Moshe Zadka

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### Abstract

This document can be considered a companion to the tutorial. It shows how to use Python, and even more importantly, how *not* to use Python.

## 1 Language Constructs You Should Not Use

While Python has relatively few gotchas compared to other languages, it still has some constructs which are only useful in corner cases, or are plain dangerous.

## 1.1 from module import \*

### Inside Function Definitions

`from module import *` is *invalid* inside function definitions. While many versions of Python do not check for the invalidity, it does not make it more valid, no more than having a smart lawyer makes a man innocent. Do not use it like that ever. Even in versions where it was accepted, it made the function execution slower, because the compiler could not be certain which names were local and which were global. In Python 2.1 this construct causes warnings, and sometimes even errors.

### At Module Level

While it is valid to use `from module import *` at module level it is usually a bad idea. For one, this loses an important property Python otherwise has — you can know where each toplevel name is defined by a simple “search” function in your favourite editor. You also open yourself to trouble in the future, if some module grows additional functions or classes.

One of the most awful questions asked on the newsgroup is why this code:

```
f = open("www")
f.read()
```

does not work. Of course, it works just fine (assuming you have a file called “www”.) But it does not work if somewhere in the module, the statement `from os import *` is present. The `os` module has a function called `open()` which returns an integer. While it is very useful, shadowing a builtin is one of its least useful properties.

Remember, you can never know for sure what names a module exports, so either take what you need — `from module import name1, name2`, or keep them in the module and access on a per-need basis — `import module; print module.name`.

### When It Is Just Fine

There are situations in which `from module import *` is just fine:

- The interactive prompt. For example, `from math import *` makes Python an amazing scientific calculator.
- When extending a module in C with a module in Python.
- When the module advertises itself as `from import * safe`.

## 1.2 Unadorned `exec`, `execfile()` and friends

The word “unadorned” refers to the use without an explicit dictionary, in which case those constructs evaluate code in the *current* environment. This is dangerous for the same reasons `from import *` is dangerous — it might step over variables you are counting on and mess up things for the rest of your code. Simply do not do that.

Bad examples:

```
>>> for name in sys.argv[1:]:
>>>     exec "%s=1" % name
>>> def func(s, **kw):
>>>     for var, val in kw.items():
>>>         exec "s.%s=val" % var # invalid!
>>> execfile("handler.py")
>>> handle()
```

Good examples:

```
>>> d = {}
>>> for name in sys.argv[1:]:
>>>     d[name] = 1
>>> def func(s, **kw):
>>>     for var, val in kw.items():
>>>         setattr(s, var, val)
>>> d={}
>>> execfile("handle.py", d, d)
>>> handle = d['handle']
>>> handle()
```

### 1.3 from module import name1, name2

This is a “don’t” which is much weaker than the previous “don’t”s but is still something you should not do if you don’t have good reasons to do that. The reason it is usually a bad idea is because you suddenly have an object which lives in two separate namespaces. When the binding in one namespace changes, the binding in the other will not, so there will be a discrepancy between them. This happens when, for example, one module is reloaded, or changes the definition of a function at runtime.

Bad example:

```
# foo.py
a = 1

# bar.py
from foo import a
if something():
    a = 2 # danger: foo.a != a
```

Good example:

```
# foo.py
a = 1

# bar.py
import foo
if something():
    foo.a = 2
```

### 1.4 except:

Python has the `except:` clause, which catches all exceptions. Since *every* error in Python raises an exception, using `except:` can make many programming errors look like runtime problems, which hinders the debugging process.

The following code shows a great example of why this is bad:

```
try:
    foo = opne("file") # misspelled "open"
except:
    sys.exit("could not open file!")
```

The second line triggers a `NameError`, which is caught by the `except` clause. The program will exit, and the error message the program prints will make you think the problem is the readability of "file" when in fact the real error has nothing to do with "file".

A better way to write the above is

```
try:
    foo = open("file")
except IOError:
    sys.exit("could not open file")
```

When this is run, Python will produce a traceback showing the `NameError`, and it will be immediately apparent what needs to be fixed.

Because `except:` catches *all* exceptions, including `SystemExit`, `KeyboardInterrupt`, and `GeneratorExit` (which is not an error and should not normally be caught by user code), using a bare `except:` is almost never a good idea. In situations where you need to catch all “normal” errors, such as in a framework that runs callbacks, you can catch the base class for all normal exceptions, `Exception`. Unfortunately in Python 2.x it is possible for third-party code to raise exceptions that do not inherit from `Exception`, so in Python 2.x there are some cases where you may have to use a bare `except:` and manually re-raise the exceptions you don’t want to catch.

## 2 Exceptions

Exceptions are a useful feature of Python. You should learn to raise them whenever something unexpected occurs, and catch them only where you can do something about them.

The following is a very popular anti-idiom

```
def get_status(file):
    if not os.path.exists(file):
        print "file not found"
        sys.exit(1)
    return open(file).readline()
```

Consider the case where the file gets deleted between the time the call to `os.path.exists()` is made and the time `open()` is called. In that case the last line will raise an `IOError`. The same thing would happen if `file` exists but has no read permission. Since testing this on a normal machine on existent and non-existent files makes it seem bugless, the test results will seem fine, and the code will get shipped. Later an unhandled `IOError` (or perhaps some other `EnvironmentError`) escapes to the user, who gets to watch the ugly traceback.

Here is a somewhat better way to do it.

```
def get_status(file):
    try:
        return open(file).readline()
    except EnvironmentError as err:
        print "Unable to open file: {}".format(err)
        sys.exit(1)
```

In this version, *either* the file gets opened and the line is read (so it works even on flaky NFS or SMB connections), or an error message is printed that provides all the available information on why the open failed, and the application is aborted.

However, even this version of `get_status()` makes too many assumptions — that it will only be used in a short running script, and not, say, in a long running server. Sure, the caller could do something like

```
try:
    status = get_status(log)
except SystemExit:
    status = None
```

But there is a better way. You should try to use as few `except` clauses in your code as you can — the ones you do use will usually be inside calls which should always succeed, or a catch-all in a main function.

So, an even better version of `get_status()` is probably

```
def get_status(file):
    return open(file).readline()
```

The caller can deal with the exception if it wants (for example, if it tries several files in a loop), or just let the exception filter upwards to *its* caller.

But the last version still has a serious problem — due to implementation details in CPython, the file would not be closed when an exception is raised until the exception handler finishes; and, worse, in other implementations (e.g., Jython) it might not be closed at all regardless of whether or not an exception is raised.

The best version of this function uses the `open()` call as a context manager, which will ensure that the file gets closed as soon as the function returns:

```
def get_status(file):
    with open(file) as fp:
        return fp.readline()
```

### 3 Using the Batteries

Every so often, people seem to be writing stuff in the Python library again, usually poorly. While the occasional module has a poor interface, it is usually much better to use the rich standard library and data types that come with Python than inventing your own.

A useful module very few people know about is `os.path`. It always has the correct path arithmetic for your operating system, and will usually be much better than whatever you come up with yourself.

Compare:

```
# ugh!
return dir+"/"+file
# better
return os.path.join(dir, file)
```

More useful functions in `os.path`: `basename()`, `dirname()` and `splittext()`.

There are also many useful built-in functions people seem not to be aware of for some reason: `min()` and `max()` can find the minimum/maximum of any sequence with comparable semantics, for example, yet many people write their own `max()/min()`. Another highly useful function is `reduce()` which can be used to repeatedly apply a binary operation to a sequence, reducing it to a single value. For example, compute a factorial with a series of multiply operations:

```
>>> n = 4
>>> import operator
>>> reduce(operator.mul, range(1, n+1))
24
```

When it comes to parsing numbers, note that `float()`, `int()` and `long()` all accept string arguments and will reject ill-formed strings by raising an `ValueError`.

## 4 Using Backslash to Continue Statements

Since Python treats a newline as a statement terminator, and since statements are often more than is comfortable to put in one line, many people do:

```
if foo.bar()['first'][0] == baz.quux(1, 2)[5:9] and \  
    calculate_number(10, 20) != forbulate(500, 360):  
    pass
```

You should realize that this is dangerous: a stray space after the `\` would make this line wrong, and stray spaces are notoriously hard to see in editors. In this case, at least it would be a syntax error, but if the code was:

```
value = foo.bar()['first'][0]*baz.quux(1, 2)[5:9] \  
        + calculate_number(10, 20)*forbulate(500, 360)
```

then it would just be subtly wrong.

It is usually much better to use the implicit continuation inside parenthesis:

This version is bulletproof:

```
value = (foo.bar()['first'][0]*baz.quux(1, 2)[5:9]  
        + calculate_number(10, 20)*forbulate(500, 360))
```

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# Functional Programming HOWTO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** A. M. Kuchling

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In this document, we'll take a tour of Python's features suitable for implementing programs in a functional style. After an introduction to the concepts of functional programming, we'll look at language features such as *iterators* and *generators* and relevant library modules such as `itertools` and `functools`.

## 1 Introduction

This section explains the basic concept of functional programming; if you're just interested in learning about Python language features, skip to the next section.

Programming languages support decomposing problems in several different ways:

- Most programming languages are **procedural**: programs are lists of instructions that tell the computer what to do with the program's input. C, Pascal, and even Unix shells are procedural languages.
- In **declarative** languages, you write a specification that describes the problem to be solved, and the language implementation figures out how to perform the computation efficiently. SQL is the declarative language you're most likely to be familiar with; a SQL query describes the data set you want to retrieve, and the SQL engine decides whether to scan tables or use indexes, which subclauses should be performed first, etc.
- **Object-oriented** programs manipulate collections of objects. Objects have internal state and support methods that query or modify this internal state in some way. Smalltalk and Java are object-oriented languages. C++ and Python are languages that support object-oriented programming, but don't force the use of object-oriented features.
- **Functional** programming decomposes a problem into a set of functions. Ideally, functions only take inputs and produce outputs, and don't have any internal state that affects the output produced for a given input. Well-known functional languages include the ML family (Standard ML, OCaml, and other variants) and Haskell.

The designers of some computer languages choose to emphasize one particular approach to programming. This often makes it difficult to write programs that use a different approach. Other languages are multi-paradigm languages that support several different approaches. Lisp, C++, and Python are multi-paradigm; you can write programs or libraries that are largely procedural, object-oriented, or functional in all of these languages. In a large program, different sections might be written using different approaches; the GUI might be object-oriented while the processing logic is procedural or functional, for example.

In a functional program, input flows through a set of functions. Each function operates on its input and produces some output. Functional style discourages functions with side effects that modify internal state or make other changes that aren't visible in the function's return value. Functions that have no side effects at all are called **purely functional**. Avoiding side effects means not using data structures that get updated as a program runs; every function's output must only depend on its input.

Some languages are very strict about purity and don't even have assignment statements such as `a=3` or `c = a + b`, but it's difficult to avoid all side effects. Printing to the screen or writing to a disk file are side effects, for example. For example, in Python a `print` statement or a `time.sleep(1)` both return no useful value; they're only called for their side effects of sending some text to the screen or pausing execution for a second.

Python programs written in functional style usually won't go to the extreme of avoiding all I/O or all assignments; instead, they'll provide a functional-appearing interface but will use non-functional features internally. For example, the implementation of a function will still use assignments to local variables, but won't modify global variables or have other side effects.

Functional programming can be considered the opposite of object-oriented programming. Objects are little capsules containing some internal state along with a collection of method calls that let you modify this state, and programs consist of making the right set of state changes. Functional programming wants to avoid state changes as much as possible and works with data flowing between functions. In Python you might combine the two approaches by writing functions that take and return instances representing objects in your application (e-mail messages, transactions, etc.).

Functional design may seem like an odd constraint to work under. Why should you avoid objects and side effects? There are theoretical and practical advantages to the functional style:

- Formal provability.
- Modularity.
- Composability.
- Ease of debugging and testing.

## 1.1 Formal provability

A theoretical benefit is that it's easier to construct a mathematical proof that a functional program is correct.

For a long time researchers have been interested in finding ways to mathematically prove programs correct. This is different from testing a program on numerous inputs and concluding that its output is usually correct, or reading a program's source code and concluding that the code looks right; the goal is instead a rigorous proof that a program produces the right result for all possible inputs.

The technique used to prove programs correct is to write down **invariants**, properties of the input data and of the program's variables that are always true. For each line of code, you then show that if invariants X and Y are true **before** the line is executed, the slightly different invariants X' and Y' are true **after** the line is executed. This continues until you reach the end of the program, at which point the invariants should match the desired conditions on the program's output.

Functional programming's avoidance of assignments arose because assignments are difficult to handle with this technique; assignments can break invariants that were true before the assignment without producing any new invariants that can be propagated onward.

Unfortunately, proving programs correct is largely impractical and not relevant to Python software. Even trivial programs require proofs that are several pages long; the proof of correctness for a moderately complicated program would be enormous, and few or none of the programs you use daily (the Python interpreter, your XML parser, your web browser) could be proven correct. Even if you wrote down or generated a proof, there would then be the question of verifying the proof; maybe there's an error in it, and you wrongly believe you've proved the program correct.

## 1.2 Modularity

A more practical benefit of functional programming is that it forces you to break apart your problem into small pieces. Programs are more modular as a result. It's easier to specify and write a small function that does one thing than a large function that performs a complicated transformation. Small functions are also easier to read and to check for errors.

## 1.3 Ease of debugging and testing

Testing and debugging a functional-style program is easier.

Debugging is simplified because functions are generally small and clearly specified. When a program doesn't work, each function is an interface point where you can check that the data are correct. You can look at the intermediate inputs and outputs to quickly isolate the function that's responsible for a bug.

Testing is easier because each function is a potential subject for a unit test. Functions don't depend on system state that needs to be replicated before running a test; instead you only have to synthesize the right input and then check that the output matches expectations.

## 1.4 Composability

As you work on a functional-style program, you'll write a number of functions with varying inputs and outputs. Some of these functions will be unavoidably specialized to a particular application, but others will be useful in a wide variety of programs. For example, a function that takes a directory path and returns all the XML files in the directory, or a function that takes a filename and returns its contents, can be applied to many different situations.

Over time you'll form a personal library of utilities. Often you'll assemble new programs by arranging existing functions in a new configuration and writing a few functions specialized for the current task.

## 2 Iterators

I'll start by looking at a Python language feature that's an important foundation for writing functional-style programs: iterators.

An iterator is an object representing a stream of data; this object returns the data one element at a time. A Python iterator must support a method called `next()` that takes no arguments and always returns the next element of the stream. If there are no more elements in the stream, `next()` must raise the `StopIteration` exception. Iterators don't have to be finite, though; it's perfectly reasonable to write an iterator that produces an infinite stream of data.

The built-in `iter()` function takes an arbitrary object and tries to return an iterator that will return the object's contents or elements, raising `TypeError` if the object doesn't support iteration. Several of Python's built-in data types support iteration, the most common being lists and dictionaries. An object is called an **iterable** object if you can get an iterator for it.

You can experiment with the iteration interface manually:

```
>>> L = [1,2,3]
>>> it = iter(L)
>>> print it
<...iterator object at ...>
>>> it.next()
1
>>> it.next()
2
>>> it.next()
3
>>> it.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
StopIteration
>>>
```

Python expects iterable objects in several different contexts, the most important being the `for` statement. In the statement `for X in Y`, `Y` must be an iterator or some object for which `iter()` can create an iterator. These two statements are equivalent:

```
for i in iter(obj):
    print i
```

```
for i in obj:
    print i
```

Iterators can be materialized as lists or tuples by using the `list()` or `tuple()` constructor functions:

```
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> t = tuple(iterator)
>>> t
(1, 2, 3)
```

Sequence unpacking also supports iterators: if you know an iterator will return N elements, you can unpack them into an N-tuple:

```
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> a,b,c = iterator
>>> a,b,c
(1, 2, 3)
```

Built-in functions such as `max()` and `min()` can take a single iterator argument and will return the largest or smallest element. The "in" and "not in" operators also support iterators: `X in iterator` is true if X is found in the stream returned by the iterator. You'll run into obvious problems if the iterator is infinite; `max()`, `min()` will never return, and if the element X never appears in the stream, the "in" and "not in" operators won't return either.

Note that you can only go forward in an iterator; there's no way to get the previous element, reset the iterator, or make a copy of it. Iterator objects can optionally provide these additional capabilities, but the iterator protocol only specifies the `next()` method. Functions may therefore consume all of the iterator's output, and if you need to do something different with the same stream, you'll have to create a new iterator.

## 2.1 Data Types That Support Iterators

We've already seen how lists and tuples support iterators. In fact, any Python sequence type, such as strings, will automatically support creation of an iterator.

Calling `iter()` on a dictionary returns an iterator that will loop over the dictionary's keys:

```
>>> m = {'Jan': 1, 'Feb': 2, 'Mar': 3, 'Apr': 4, 'May': 5, 'Jun': 6,
...      'Jul': 7, 'Aug': 8, 'Sep': 9, 'Oct': 10, 'Nov': 11, 'Dec': 12}
>>> for key in m:
...     print key, m[key]
Mar 3
Feb 2
Aug 8
Sep 9
Apr 4
Jun 6
Jul 7
Jan 1
May 5
Nov 11
Dec 12
Oct 10
```

Note that the order is essentially random, because it's based on the hash ordering of the objects in the dictionary.

Applying `iter()` to a dictionary always loops over the keys, but dictionaries have methods that return other iterators. If you want to iterate over keys, values, or key/value pairs, you can explicitly call the `iterkeys()`,

`itervalues()`, or `iteritems()` methods to get an appropriate iterator.

The `dict()` constructor can accept an iterator that returns a finite stream of `(key, value)` tuples:

```
>>> L = [('Italy', 'Rome'), ('France', 'Paris'), ('US', 'Washington DC')]
>>> dict(iter(L))
{'Italy': 'Rome', 'US': 'Washington DC', 'France': 'Paris'}
```

Files also support iteration by calling the `readline()` method until there are no more lines in the file. This means you can read each line of a file like this:

```
for line in file:
    # do something for each line
    ...
```

Sets can take their contents from an iterable and let you iterate over the set's elements:

```
S = set((2, 3, 5, 7, 11, 13))
for i in S:
    print i
```

### 3 Generator expressions and list comprehensions

Two common operations on an iterator's output are 1) performing some operation for every element, 2) selecting a subset of elements that meet some condition. For example, given a list of strings, you might want to strip off trailing whitespace from each line or extract all the strings containing a given substring.

List comprehensions and generator expressions (short form: "listcomps" and "genexps") are a concise notation for such operations, borrowed from the functional programming language Haskell (<http://www.haskell.org/>). You can strip all the whitespace from a stream of strings with the following code:

```
line_list = [' line 1\n', 'line 2 \n', ...]

# Generator expression -- returns iterator
stripped_iter = (line.strip() for line in line_list)

# List comprehension -- returns list
stripped_list = [line.strip() for line in line_list]
```

You can select only certain elements by adding an "if" condition:

```
stripped_list = [line.strip() for line in line_list
                 if line != ""]
```

With a list comprehension, you get back a Python list; `stripped_list` is a list containing the resulting lines, not an iterator. Generator expressions return an iterator that computes the values as necessary, not needing to materialize all the values at once. This means that list comprehensions aren't useful if you're working with iterators that return an infinite stream or a very large amount of data. Generator expressions are preferable in these situations.

Generator expressions are surrounded by parentheses ("`()`") and list comprehensions are surrounded by square brackets ("`[]`"). Generator expressions have the form:

```
( expression for expr in sequence1
    if condition1
    for expr2 in sequence2
    if condition2
    for expr3 in sequence3 ...
    if condition3
```

```

    for exprN in sequenceN
    if conditionN )

```

Again, for a list comprehension only the outside brackets are different (square brackets instead of parentheses).

The elements of the generated output will be the successive values of `expression`. The `if` clauses are all optional; if present, `expression` is only evaluated and added to the result when `condition` is true.

Generator expressions always have to be written inside parentheses, but the parentheses signalling a function call also count. If you want to create an iterator that will be immediately passed to a function you can write:

```
obj_total = sum(obj.count for obj in list_all_objects())
```

The `for...in` clauses contain the sequences to be iterated over. The sequences do not have to be the same length, because they are iterated over from left to right, **not** in parallel. For each element in `sequence1`, `sequence2` is looped over from the beginning. `sequence3` is then looped over for each resulting pair of elements from `sequence1` and `sequence2`.

To put it another way, a list comprehension or generator expression is equivalent to the following Python code:

```

for expr1 in sequence1:
    if not (condition1):
        continue # Skip this element
    for expr2 in sequence2:
        if not (condition2):
            continue # Skip this element
        ...
        for exprN in sequenceN:
            if not (conditionN):
                continue # Skip this element

        # Output the value of
        # the expression.

```

This means that when there are multiple `for...in` clauses but no `if` clauses, the length of the resulting output will be equal to the product of the lengths of all the sequences. If you have two lists of length 3, the output list is 9 elements long:

```

>>> seq1 = 'abc'
>>> seq2 = (1,2,3)
>>> [(x,y) for x in seq1 for y in seq2]
[('a', 1), ('a', 2), ('a', 3),
 ('b', 1), ('b', 2), ('b', 3),
 ('c', 1), ('c', 2), ('c', 3)]

```

To avoid introducing an ambiguity into Python's grammar, if `expression` is creating a tuple, it must be surrounded with parentheses. The first list comprehension below is a syntax error, while the second one is correct:

```

# Syntax error
[ x,y for x in seq1 for y in seq2]
# Correct
[ (x,y) for x in seq1 for y in seq2]

```

## 4 Generators

Generators are a special class of functions that simplify the task of writing iterators. Regular functions compute a value and return it, but generators return an iterator that returns a stream of values.

You're doubtless familiar with how regular function calls work in Python or C. When you call a function, it gets a private namespace where its local variables are created. When the function reaches a `return` statement, the local variables are destroyed and the value is returned to the caller. A later call to the same function creates a new private namespace and a fresh set of local variables. But, what if the local variables weren't thrown away on exiting a function? What if you could later resume the function where it left off? This is what generators provide; they can be thought of as resumable functions.

Here's the simplest example of a generator function:

```
def generate_ints(N):
    for i in range(N):
        yield i
```

Any function containing a `yield` keyword is a generator function; this is detected by Python's *bytecode* compiler which compiles the function specially as a result.

When you call a generator function, it doesn't return a single value; instead it returns a generator object that supports the iterator protocol. On executing the `yield` expression, the generator outputs the value of `i`, similar to a `return` statement. The big difference between `yield` and a `return` statement is that on reaching a `yield` the generator's state of execution is suspended and local variables are preserved. On the next call to the generator's `.next()` method, the function will resume executing.

Here's a sample usage of the `generate_ints()` generator:

```
>>> gen = generate_ints(3)
>>> gen
<generator object generate_ints at ...>
>>> gen.next()
0
>>> gen.next()
1
>>> gen.next()
2
>>> gen.next()
Traceback (most recent call last):
  File "stdin", line 1, in ?
  File "stdin", line 2, in generate_ints
StopIteration
```

You could equally write `for i in generate_ints(5)`, or `a,b,c = generate_ints(3)`.

Inside a generator function, the `return` statement can only be used without a value, and signals the end of the procession of values; after executing a `return` the generator cannot return any further values. `return` with a value, such as `return 5`, is a syntax error inside a generator function. The end of the generator's results can also be indicated by raising `StopIteration` manually, or by just letting the flow of execution fall off the bottom of the function.

You could achieve the effect of generators manually by writing your own class and storing all the local variables of the generator as instance variables. For example, returning a list of integers could be done by setting `self.count` to 0, and having the `next()` method increment `self.count` and return it. However, for a moderately complicated generator, writing a corresponding class can be much messier.

The test suite included with Python's library, `test_generators.py`, contains a number of more interesting examples. Here's one generator that implements an in-order traversal of a tree using generators recursively.

```
# A recursive generator that generates Tree leaves in in-order.
def inorder(t):
    if t:
        for x in inorder(t.left):
```

```

        yield x

    yield t.label

    for x in inorder(t.right):
        yield x

```

Two other examples in `test_generators.py` produce solutions for the N-Queens problem (placing N queens on an NxN chess board so that no queen threatens another) and the Knight's Tour (finding a route that takes a knight to every square of an NxN chessboard without visiting any square twice).

## 4.1 Passing values into a generator

In Python 2.4 and earlier, generators only produced output. Once a generator's code was invoked to create an iterator, there was no way to pass any new information into the function when its execution is resumed. You could hack together this ability by making the generator look at a global variable or by passing in some mutable object that callers then modify, but these approaches are messy.

In Python 2.5 there's a simple way to pass values into a generator. `yield` became an expression, returning a value that can be assigned to a variable or otherwise operated on:

```
val = (yield i)
```

I recommend that you **always** put parentheses around a `yield` expression when you're doing something with the returned value, as in the above example. The parentheses aren't always necessary, but it's easier to always add them instead of having to remember when they're needed.

(PEP 342 explains the exact rules, which are that a `yield`-expression must always be parenthesized except when it occurs at the top-level expression on the right-hand side of an assignment. This means you can write `val = yield i` but have to use parentheses when there's an operation, as in `val = (yield i) + 12`.)

Values are sent into a generator by calling its `send(value)` method. This method resumes the generator's code and the `yield` expression returns the specified value. If the regular `next()` method is called, the `yield` returns `None`.

Here's a simple counter that increments by 1 and allows changing the value of the internal counter.

```

def counter (maximum):
    i = 0
    while i < maximum:
        val = (yield i)
        # If value provided, change counter
        if val is not None:
            i = val
        else:
            i += 1

```

And here's an example of changing the counter:

```

>>> it = counter(10)
>>> print it.next()
0
>>> print it.next()
1
>>> print it.send(8)
8
>>> print it.next()
9
>>> print it.next()

```

```
Traceback (most recent call last):
  File "t.py", line 15, in ?
    print it.next()
StopIteration
```

Because `yield` will often be returning `None`, you should always check for this case. Don't just use its value in expressions unless you're sure that the `send()` method will be the only method used resume your generator function.

In addition to `send()`, there are two other new methods on generators:

- `throw(type, value=None, traceback=None)` is used to raise an exception inside the generator; the exception is raised by the `yield` expression where the generator's execution is paused.
- `close()` raises a `GeneratorExit` exception inside the generator to terminate the iteration. On receiving this exception, the generator's code must either raise `GeneratorExit` or `StopIteration`; catching the exception and doing anything else is illegal and will trigger a `RuntimeError`. `close()` will also be called by Python's garbage collector when the generator is garbage-collected.

If you need to run cleanup code when a `GeneratorExit` occurs, I suggest using a `try: ... finally: suite` instead of catching `GeneratorExit`.

The cumulative effect of these changes is to turn generators from one-way producers of information into both producers and consumers.

Generators also become **coroutines**, a more generalized form of subroutines. Subroutines are entered at one point and exited at another point (the top of the function, and a `return` statement), but coroutines can be entered, exited, and resumed at many different points (the `yield` statements).

## 5 Built-in functions

Let's look in more detail at built-in functions often used with iterators.

Two of Python's built-in functions, `map()` and `filter()`, are somewhat obsolete; they duplicate the features of list comprehensions but return actual lists instead of iterators.

`map(f, iterA, iterB, ...)` returns a list containing `f(iterA[0], iterB[0])`, `f(iterA[1], iterB[1])`, `f(iterA[2], iterB[2])`, ....

```
>>> def upper(s):
...     return s.upper()
>>> map(upper, ['sentence', 'fragment'])
['SENTENCE', 'FRAGMENT']
>>> [upper(s) for s in ['sentence', 'fragment']]
['SENTENCE', 'FRAGMENT']
```

As shown above, you can achieve the same effect with a list comprehension. The `itertools.imap()` function does the same thing but can handle infinite iterators; it'll be discussed later, in the section on the `itertools` module.

`filter(predicate, iter)` returns a list that contains all the sequence elements that meet a certain condition, and is similarly duplicated by list comprehensions. A **predicate** is a function that returns the truth value of some condition; for use with `filter()`, the predicate must take a single value.

```
>>> def is_even(x):
...     return (x % 2) == 0
>>> filter(is_even, range(10))
[0, 2, 4, 6, 8]
```

This can also be written as a list comprehension:

```
>>> [x for x in range(10) if is_even(x)]
[0, 2, 4, 6, 8]
```

`filter()` also has a counterpart in the `itertools` module, `itertools.ifilter()`, that returns an iterator and can therefore handle infinite sequences just as `itertools.imap()` can.

`reduce(func, iter, [initial_value])` doesn't have a counterpart in the `itertools` module because it cumulatively performs an operation on all the iterable's elements and therefore can't be applied to infinite iterables. `func` must be a function that takes two elements and returns a single value. `reduce()` takes the first two elements `A` and `B` returned by the iterator and calculates `func(A, B)`. It then requests the third element, `C`, calculates `func(func(A, B), C)`, combines this result with the fourth element returned, and continues until the iterable is exhausted. If the iterable returns no values at all, a `TypeError` exception is raised. If the initial value is supplied, it's used as a starting point and `func(initial_value, A)` is the first calculation.

```
>>> import operator
>>> reduce(operator.concat, ['A', 'BB', 'C'])
'ABBC'
>>> reduce(operator.concat, [])
Traceback (most recent call last):
...
TypeError: reduce() of empty sequence with no initial value
>>> reduce(operator.mul, [1,2,3], 1)
6
>>> reduce(operator.mul, [], 1)
1
```

If you use `operator.add()` with `reduce()`, you'll add up all the elements of the iterable. This case is so common that there's a special built-in called `sum()` to compute it:

```
>>> reduce(operator.add, [1,2,3,4], 0)
10
>>> sum([1,2,3,4])
10
>>> sum([])
0
```

For many uses of `reduce()`, though, it can be clearer to just write the obvious `for` loop:

```
# Instead of:
product = reduce(operator.mul, [1,2,3], 1)

# You can write:
product = 1
for i in [1,2,3]:
    product *= i
```

`enumerate(iter)` counts off the elements in the iterable, returning 2-tuples containing the count and each element.

```
>>> for item in enumerate(['subject', 'verb', 'object']):
...     print item
(0, 'subject')
(1, 'verb')
(2, 'object')
```

`enumerate()` is often used when looping through a list and recording the indexes at which certain conditions are met:

```
f = open('data.txt', 'r')
for i, line in enumerate(f):
```

```

    if line.strip() == '':
        print 'Blank line at line #%i' % i

```

sorted(iterable, [cmp=None], [key=None], [reverse=False]) collects all the elements of the iterable into a list, sorts the list, and returns the sorted result. The cmp, key, and reverse arguments are passed through to the constructed list's .sort() method.

```

>>> import random
>>> # Generate 8 random numbers between [0, 10000)
>>> rand_list = random.sample(range(10000), 8)
>>> rand_list
[769, 7953, 9828, 6431, 8442, 9878, 6213, 2207]
>>> sorted(rand_list)
[769, 2207, 6213, 6431, 7953, 8442, 9828, 9878]
>>> sorted(rand_list, reverse=True)
[9878, 9828, 8442, 7953, 6431, 6213, 2207, 769]

```

(For a more detailed discussion of sorting, see the Sorting mini-HOWTO in the Python wiki at <http://wiki.python.org/moin/HowTo/Sorting>.)

The any(iter) and all(iter) built-ins look at the truth values of an iterable's contents. any() returns True if any element in the iterable is a true value, and all() returns True if all of the elements are true values:

```

>>> any([0, 1, 0])
True
>>> any([0, 0, 0])
False
>>> any([1, 1, 1])
True
>>> all([0, 1, 0])
False
>>> all([0, 0, 0])
False
>>> all([1, 1, 1])
True

```

## 6 Small functions and the lambda expression

When writing functional-style programs, you'll often need little functions that act as predicates or that combine elements in some way.

If there's a Python built-in or a module function that's suitable, you don't need to define a new function at all:

```

stripped_lines = [line.strip() for line in lines]
existing_files = filter(os.path.exists, file_list)

```

If the function you need doesn't exist, you need to write it. One way to write small functions is to use the lambda statement. lambda takes a number of parameters and an expression combining these parameters, and creates a small function that returns the value of the expression:

```

lowercase = lambda x: x.lower()

print_assign = lambda name, value: name + '=' + str(value)

add = lambda x, y: x+y

```

An alternative is to just use the def statement and define a function in the usual way:

```

def lowercase(x):
    return x.lower()

def print_assign(name, value):
    return name + '=' + str(value)

def adder(x, y):
    return x + y

```

Which alternative is preferable? That's a style question; my usual course is to avoid using `lambda`.

One reason for my preference is that `lambda` is quite limited in the functions it can define. The result has to be computable as a single expression, which means you can't have multiway `if... elif... else` comparisons or `try... except` statements. If you try to do too much in a `lambda` statement, you'll end up with an overly complicated expression that's hard to read. Quick, what's the following code doing?

```
total = reduce(lambda a, b: (0, a[1] + b[1]), items)[1]
```

You can figure it out, but it takes time to disentangle the expression to figure out what's going on. Using a short nested `def` statements makes things a little bit better:

```

def combine (a, b):
    return 0, a[1] + b[1]

total = reduce(combine, items)[1]

```

But it would be best of all if I had simply used a `for` loop:

```

total = 0
for a, b in items:
    total += b

```

Or the `sum()` built-in and a generator expression:

```
total = sum(b for a, b in items)
```

Many uses of `reduce()` are clearer when written as `for` loops.

Fredrik Lundh once suggested the following set of rules for refactoring uses of `lambda`:

1. Write a `lambda` function.
2. Write a comment explaining what the heck that `lambda` does.
3. Study the comment for a while, and think of a name that captures the essence of the comment.
4. Convert the `lambda` to a `def` statement, using that name.
5. Remove the comment.

I really like these rules, but you're free to disagree about whether this `lambda`-free style is better.

## 7 The `itertools` module

The `itertools` module contains a number of commonly-used iterators as well as functions for combining several iterators. This section will introduce the module's contents by showing small examples.

The module's functions fall into a few broad classes:

- Functions that create a new iterator based on an existing iterator.
- Functions for treating an iterator's elements as function arguments.

- Functions for selecting portions of an iterator's output.
- A function for grouping an iterator's output.

## 7.1 Creating new iterators

`itertools.count(n)` returns an infinite stream of integers, increasing by 1 each time. You can optionally supply the starting number, which defaults to 0:

```
itertools.count() =>
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
itertools.count(10) =>
  10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...
```

`itertools.cycle(iter)` saves a copy of the contents of a provided iterable and returns a new iterator that returns its elements from first to last. The new iterator will repeat these elements infinitely.

```
itertools.cycle([1,2,3,4,5]) =>
  1, 2, 3, 4, 5, 1, 2, 3, 4, 5, ...
```

`itertools.repeat(elem, [n])` returns the provided element `n` times, or returns the element endlessly if `n` is not provided.

```
itertools.repeat('abc') =>
  abc, ...
itertools.repeat('abc', 5) =>
  abc, abc, abc, abc, abc
```

`itertools.chain(iterA, iterB, ...)` takes an arbitrary number of iterables as input, and returns all the elements of the first iterator, then all the elements of the second, and so on, until all of the iterables have been exhausted.

```
itertools.chain(['a', 'b', 'c'], (1, 2, 3)) =>
  a, b, c, 1, 2, 3
```

`itertools.izip(iterA, iterB, ...)` takes one element from each iterable and returns them in a tuple:

```
itertools.izip(['a', 'b', 'c'], (1, 2, 3)) =>
  ('a', 1), ('b', 2), ('c', 3)
```

It's similar to the built-in `zip()` function, but doesn't construct an in-memory list and exhaust all the input iterators before returning; instead tuples are constructed and returned only if they're requested. (The technical term for this behaviour is [lazy evaluation](#).)

This iterator is intended to be used with iterables that are all of the same length. If the iterables are of different lengths, the resulting stream will be the same length as the shortest iterable.

```
itertools.izip(['a', 'b'], (1, 2, 3)) =>
  ('a', 1), ('b', 2)
```

You should avoid doing this, though, because an element may be taken from the longer iterators and discarded. This means you can't go on to use the iterators further because you risk skipping a discarded element.

`itertools.islice(iter, [start], stop, [step])` returns a stream that's a slice of the iterator. With a single `stop` argument, it will return the first `stop` elements. If you supply a starting index, you'll get `stop-start` elements, and if you supply a value for `step`, elements will be skipped accordingly. Unlike Python's string and list slicing, you can't use negative values for `start`, `stop`, or `step`.

```
itertools.islice(range(10), 8) =>
  0, 1, 2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8) =>
```

```
2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8, 2) =>
2, 4, 6
```

`itertools.tee(iter, [n])` replicates an iterator; it returns `n` independent iterators that will all return the contents of the source iterator. If you don't supply a value for `n`, the default is 2. Replicating iterators requires saving some of the contents of the source iterator, so this can consume significant memory if the iterator is large and one of the new iterators is consumed more than the others.

```
itertools.tee(itertools.count()) =>
iterA, iterB
```

```
where iterA ->
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
```

```
and iterB ->
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
```

## 7.2 Calling functions on elements

Two functions are used for calling other functions on the contents of an iterable.

`itertools.imap(f, iterA, iterB, ...)` returns a stream containing `f(iterA[0], iterB[0])`, `f(iterA[1], iterB[1])`, `f(iterA[2], iterB[2])`, ...:

```
itertools.imap(operator.add, [5, 6, 5], [1, 2, 3]) =>
6, 8, 8
```

The `operator` module contains a set of functions corresponding to Python's operators. Some examples are `operator.add(a, b)` (adds two values), `operator.ne(a, b)` (same as `a!=b`), and `operator.attrgetter('id')` (returns a callable that fetches the "id" attribute).

`itertools.starmap(func, iter)` assumes that the iterable will return a stream of tuples, and calls `f()` using these tuples as the arguments:

```
itertools.starmap(os.path.join,
                  [('/usr', 'bin', 'java'), ('/bin', 'python'),
                   ('/usr', 'bin', 'perl'), ('/usr', 'bin', 'ruby')])
=>
/usr/bin/java, /bin/python, /usr/bin/perl, /usr/bin/ruby
```

## 7.3 Selecting elements

Another group of functions chooses a subset of an iterator's elements based on a predicate.

`itertools.ifilter(predicate, iter)` returns all the elements for which the predicate returns true:

```
def is_even(x):
    return (x % 2) == 0
```

```
itertools.ifilter(is_even, itertools.count()) =>
0, 2, 4, 6, 8, 10, 12, 14, ...
```

`itertools.ifilterfalse(predicate, iter)` is the opposite, returning all elements for which the predicate returns false:

```
itertools.ifilterfalse(is_even, itertools.count()) =>
1, 3, 5, 7, 9, 11, 13, 15, ...
```

`itertools.takewhile(predicate, iter)` returns elements for as long as the predicate returns true. Once the predicate returns false, the iterator will signal the end of its results.

```
def less_than_10(x):
    return (x < 10)
```

```
itertools.takewhile(less_than_10, itertools.count()) =>
    0, 1, 2, 3, 4, 5, 6, 7, 8, 9
```

```
itertools.takewhile(is_even, itertools.count()) =>
    0
```

`itertools.dropwhile(predicate, iter)` discards elements while the predicate returns true, and then returns the rest of the iterable's results.

```
itertools.dropwhile(less_than_10, itertools.count()) =>
    10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...
```

```
itertools.dropwhile(is_even, itertools.count()) =>
    1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ...
```

## 7.4 Grouping elements

The last function I'll discuss, `itertools.groupby(iter, key_func=None)`, is the most complicated. `key_func(elem)` is a function that can compute a key value for each element returned by the iterable. If you don't supply a key function, the key is simply each element itself.

`groupby()` collects all the consecutive elements from the underlying iterable that have the same key value, and returns a stream of 2-tuples containing a key value and an iterator for the elements with that key.

```
city_list = [('Decatur', 'AL'), ('Huntsville', 'AL'), ('Selma', 'AL'),
             ('Anchorage', 'AK'), ('Nome', 'AK'),
             ('Flagstaff', 'AZ'), ('Phoenix', 'AZ'), ('Tucson', 'AZ'),
             ...
            ]
```

```
def get_state ((city, state)):
    return state
```

```
itertools.groupby(city_list, get_state) =>
    ('AL', iterator-1),
    ('AK', iterator-2),
    ('AZ', iterator-3), ...
```

where

```
iterator-1 =>
    ('Decatur', 'AL'), ('Huntsville', 'AL'), ('Selma', 'AL')
```

```
iterator-2 =>
    ('Anchorage', 'AK'), ('Nome', 'AK')
```

```
iterator-3 =>
    ('Flagstaff', 'AZ'), ('Phoenix', 'AZ'), ('Tucson', 'AZ')
```

`groupby()` assumes that the underlying iterable's contents will already be sorted based on the key. Note that the returned iterators also use the underlying iterable, so you have to consume the results of `iterator-1` before requesting `iterator-2` and its corresponding key.

## 8 The functools module

The `functools` module in Python 2.5 contains some higher-order functions. A **higher-order function** takes one or more functions as input and returns a new function. The most useful tool in this module is the `functools.partial()` function.

For programs written in a functional style, you'll sometimes want to construct variants of existing functions that have some of the parameters filled in. Consider a Python function `f(a, b, c)`; you may wish to create a new function `g(b, c)` that's equivalent to `f(1, b, c)`; you're filling in a value for one of `f()`'s parameters. This is called "partial function application".

The constructor for `partial` takes the arguments `(function, arg1, arg2, ... kwarg1=value1, kwarg2=value2)`. The resulting object is callable, so you can just call it to invoke `function` with the filled-in arguments.

Here's a small but realistic example:

```
import functools

def log (message, subsystem):
    "Write the contents of 'message' to the specified subsystem."
    print '%s: %s' % (subsystem, message)
    ...

server_log = functools.partial(log, subsystem='server')
server_log('Unable to open socket')
```

### 8.1 The operator module

The `operator` module was mentioned earlier. It contains a set of functions corresponding to Python's operators. These functions are often useful in functional-style code because they save you from writing trivial functions that perform a single operation.

Some of the functions in this module are:

- Math operations: `add()`, `sub()`, `mul()`, `div()`, `floordiv()`, `abs()`, ...
- Logical operations: `not_()`, `truth()`.
- Bitwise operations: `and_()`, `or_()`, `invert()`.
- Comparisons: `eq()`, `ne()`, `lt()`, `le()`, `gt()`, and `ge()`.
- Object identity: `is_()`, `is_not()`.

Consult the operator module's documentation for a complete list.

## 9 Revision History and Acknowledgements

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Version 0.1: posted June 30 2006.

Version 0.11: posted July 1 2006. Typo fixes.

Version 0.2: posted July 10 2006. Merged `genexp` and `listcomp` sections into one. Typo fixes.

Version 0.21: Added more references suggested on the tutor mailing list.

Version 0.30: Adds a section on the `functional` module written by Collin Winter; adds short section on the `operator` module; a few other edits.

## 10 References

### 10.1 General

**Structure and Interpretation of Computer Programs**, by Harold Abelson and Gerald Jay Sussman with Julie Sussman. Full text at <http://mitpress.mit.edu/sicp/>. In this classic textbook of computer science, chapters 2 and 3 discuss the use of sequences and streams to organize the data flow inside a program. The book uses Scheme for its examples, but many of the design approaches described in these chapters are applicable to functional-style Python code.

<http://www.defmacro.org/ramblings/fp.html>: A general introduction to functional programming that uses Java examples and has a lengthy historical introduction.

[http://en.wikipedia.org/wiki/Functional\\_programming](http://en.wikipedia.org/wiki/Functional_programming): General Wikipedia entry describing functional programming.

<http://en.wikipedia.org/wiki/Coroutine>: Entry for coroutines.

<http://en.wikipedia.org/wiki/Currying>: Entry for the concept of currying.

### 10.2 Python-specific

<http://gnosis.cx/TPiP/>: The first chapter of David Mertz's book *Text Processing in Python* discusses functional programming for text processing, in the section titled "Utilizing Higher-Order Functions in Text Processing".

Mertz also wrote a 3-part series of articles on functional programming for IBM's DeveloperWorks site; see [part 1](#), [part 2](#), and [part 3](#),

### 10.3 Python documentation

Documentation for the `itertools` module.

Documentation for the `operator` module.

**PEP 289**: "Generator Expressions"

**PEP 342**: "Coroutines via Enhanced Generators" describes the new generator features in Python 2.5.

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# Logging HOWTO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Vinay Sajip <vinay\_sajip at red-dove dot com>

# 1 Basic Logging Tutorial

Logging is a means of tracking events that happen when some software runs. The software's developer adds logging calls to their code to indicate that certain events have occurred. An event is described by a descriptive message which can optionally contain variable data (i.e. data that is potentially different for each occurrence of the event). Events also have an importance which the developer ascribes to the event; the importance can also be called the *level* or *severity*.

## 1.1 When to use logging

Logging provides a set of convenience functions for simple logging usage. These are `debug()`, `info()`, `warning()`, `error()` and `critical()`. To determine when to use logging, see the table below, which states, for each of a set of common tasks, the best tool to use for it.

Task you want to perform	The best tool for the task
Display console output for ordinary usage of a command line script or program	<code>print()</code>
Report events that occur during normal operation of a program (e.g. for status monitoring or fault investigation)	<code>logging.info()</code> (or <code>logging.debug()</code> for very detailed output for diagnostic purposes)
Issue a warning regarding a particular runtime event	<code>warnings.warn()</code> in library code if the issue is avoidable and the client application should be modified to eliminate the warning <code>logging.warning()</code> if there is nothing the client application can do about the situation, but the event should still be noted
Report an error regarding a particular runtime event	Raise an exception
Report suppression of an error without raising an exception (e.g. error handler in a long-running server process)	<code>logging.error()</code> , <code>logging.exception()</code> or <code>logging.critical()</code> as appropriate for the specific error and application domain

The logging functions are named after the level or severity of the events they are used to track. The standard levels and their applicability are described below (in increasing order of severity):

Level	When it's used
DEBUG	Detailed information, typically of interest only when diagnosing problems.
INFO	Confirmation that things are working as expected.
WARNING	An indication that something unexpected happened, or indicative of some problem in the near future (e.g. 'disk space low'). The software is still working as expected.
ERROR	Due to a more serious problem, the software has not been able to perform some function.
CRITICAL	A serious error, indicating that the program itself may be unable to continue running.

The default level is `WARNING`, which means that only events of this level and above will be tracked, unless the logging package is configured to do otherwise.

Events that are tracked can be handled in different ways. The simplest way of handling tracked events is to print them to the console. Another common way is to write them to a disk file.

## 1.2 A simple example

A very simple example is:

```
import logging
logging.warning('Watch out!') # will print a message to the console
logging.info('I told you so') # will not print anything
```

If you type these lines into a script and run it, you'll see:

```
WARNING:root:Watch out!
```

printed out on the console. The INFO message doesn't appear because the default level is WARNING. The printed message includes the indication of the level and the description of the event provided in the logging call, i.e. 'Watch out!'. Don't worry about the 'root' part for now: it will be explained later. The actual output can be formatted quite flexibly if you need that; formatting options will also be explained later.

### 1.3 Logging to a file

A very common situation is that of recording logging events in a file, so let's look at that next:

#### import logging

```
logging.basicConfig(filename='example.log', level=logging.DEBUG)
logging.debug('This message should go to the log file')
logging.info('So should this')
logging.warning('And this, too')
```

And now if we open the file and look at what we have, we should find the log messages:

```
DEBUG:root:This message should go to the log file
INFO:root:So should this
WARNING:root:And this, too
```

This example also shows how you can set the logging level which acts as the threshold for tracking. In this case, because we set the threshold to DEBUG, all of the messages were printed.

If you want to set the logging level from a command-line option such as:

```
--log=INFO
```

and you have the value of the parameter passed for `--log` in some variable *loglevel*, you can use:

```
getattr(logging, loglevel.upper())
```

to get the value which you'll pass to `basicConfig()` via the *level* argument. You may want to error check any user input value, perhaps as in the following example:

```
# assuming loglevel is bound to the string value obtained from the
# command line argument. Convert to upper case to allow the user to
# specify --log=DEBUG or --log=debug
numeric_level = getattr(logging, loglevel.upper(), None)
if not isinstance(numeric_level, int):
    raise ValueError('Invalid log level: %s' % loglevel)
logging.basicConfig(level=numeric_level, ...)
```

The call to `basicConfig()` should come *before* any calls to `debug()`, `info()` etc. As it's intended as a one-off simple configuration facility, only the first call will actually do anything: subsequent calls are effectively no-ops.

If you run the above script several times, the messages from successive runs are appended to the file *example.log*. If you want each run to start afresh, not remembering the messages from earlier runs, you can specify the *filemode* argument, by changing the call in the above example to:

```
logging.basicConfig(filename='example.log', filemode='w', level=logging.DEBUG)
```

The output will be the same as before, but the log file is no longer appended to, so the messages from earlier runs are lost.

### 1.4 Logging from multiple modules

If your program consists of multiple modules, here's an example of how you could organize logging in it:

```

# myapp.py
import logging
import mylib

def main():
    logging.basicConfig(filename='myapp.log', level=logging.INFO)
    logging.info('Started')
    mylib.do_something()
    logging.info('Finished')

if __name__ == '__main__':
    main()

# mylib.py
import logging

def do_something():
    logging.info('Doing something')

```

If you run *myapp.py*, you should see this in *myapp.log*:

```

INFO:root:Started
INFO:root:Doing something
INFO:root:Finished

```

which is hopefully what you were expecting to see. You can generalize this to multiple modules, using the pattern in *mylib.py*. Note that for this simple usage pattern, you won't know, by looking in the log file, *where* in your application your messages came from, apart from looking at the event description. If you want to track the location of your messages, you'll need to refer to the documentation beyond the tutorial level – see [Advanced Logging Tutorial](#).

## 1.5 Logging variable data

To log variable data, use a format string for the event description message and append the variable data as arguments. For example:

```

import logging
logging.warning('%s before you %s', 'Look', 'leap!')

```

will display:

```

WARNING:root:Look before you leap!

```

As you can see, merging of variable data into the event description message uses the old, %-style of string formatting. This is for backwards compatibility: the logging package pre-dates newer formatting options such as `str.format()` and `string.Template`. These newer formatting options *are* supported, but exploring them is outside the scope of this tutorial.

## 1.6 Changing the format of displayed messages

To change the format which is used to display messages, you need to specify the format you want to use:

```

import logging
logging.basicConfig(format='%(levelname)s: %(message)s', level=logging.DEBUG)
logging.debug('This message should appear on the console')
logging.info('So should this')
logging.warning('And this, too')

```

which would print:

```
DEBUG:This message should appear on the console
INFO:So should this
WARNING:And this, too
```

Notice that the 'root' which appeared in earlier examples has disappeared. For a full set of things that can appear in format strings, you can refer to the documentation for *logrecord-attributes*, but for simple usage, you just need the *levelname* (severity), *message* (event description, including variable data) and perhaps to display when the event occurred. This is described in the next section.

## 1.7 Displaying the date/time in messages

To display the date and time of an event, you would place '%(asctime)s' in your format string:

```
import logging
logging.basicConfig(format='%(asctime)s %(message)s')
logging.warning('is when this event was logged.')
```

which should print something like this:

```
2010-12-12 11:41:42,612 is when this event was logged.
```

The default format for date/time display (shown above) is ISO8601. If you need more control over the formatting of the date/time, provide a *datefmt* argument to *basicConfig*, as in this example:

```
import logging
logging.basicConfig(format='%(asctime)s %(message)s', datefmt='%m/%d/%Y %I:%M:%S %p')
logging.warning('is when this event was logged.')
```

which would display something like this:

```
12/12/2010 11:46:36 AM is when this event was logged.
```

The format of the *datefmt* argument is the same as supported by *time.strftime()*.

## 1.8 Next Steps

That concludes the basic tutorial. It should be enough to get you up and running with logging. There's a lot more that the logging package offers, but to get the best out of it, you'll need to invest a little more of your time in reading the following sections. If you're ready for that, grab some of your favourite beverage and carry on.

If your logging needs are simple, then use the above examples to incorporate logging into your own scripts, and if you run into problems or don't understand something, please post a question on the *comp.lang.python* Usenet group (available at <http://groups.google.com/group/comp.lang.python>) and you should receive help before too long.

Still here? You can carry on reading the next few sections, which provide a slightly more advanced/in-depth tutorial than the basic one above. After that, you can take a look at the *logging-cookbook*.

## 2 Advanced Logging Tutorial

The logging library takes a modular approach and offers several categories of components: loggers, handlers, filters, and formatters.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.

- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.

Logging is performed by calling methods on instances of the `Logger` class (hereafter called *loggers*). Each instance has a name, and they are conceptually arranged in a namespace hierarchy using dots (periods) as separators. For example, a logger named 'scan' is the parent of loggers 'scan.text', 'scan.html' and 'scan.pdf'. Logger names can be anything you want, and indicate the area of an application in which a logged message originates.

A good convention to use when naming loggers is to use a module-level logger, in each module which uses logging, named as follows:

```
logger = logging.getLogger(__name__)
```

This means that logger names track the package/module hierarchy, and it's intuitively obvious where events are logged just from the logger name.

The root of the hierarchy of loggers is called the root logger. That's the logger used by the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, which just call the same-named method of the root logger. The functions and the methods have the same signatures. The root logger's name is printed as 'root' in the logged output.

It is, of course, possible to log messages to different destinations. Support is included in the package for writing log messages to files, HTTP GET/POST locations, email via SMTP, generic sockets, or OS-specific logging mechanisms such as syslog or the Windows NT event log. Destinations are served by *handler* classes. You can create your own log destination class if you have special requirements not met by any of the built-in handler classes.

By default, no destination is set for any logging messages. You can specify a destination (such as console or file) by using `basicConfig()` as in the tutorial examples. If you call the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, they will check to see if no destination is set; and if one is not set, they will set a destination of the console (`sys.stderr`) and a default format for the displayed message before delegating to the root logger to do the actual message output.

The default format set by `basicConfig()` for messages is:

```
severity:logger name:message
```

You can change this by passing a format string to `basicConfig()` with the *format* keyword argument. For all options regarding how a format string is constructed, see *formatter-objects*.

## 2.1 Loggers

`Logger` objects have a threefold job. First, they expose several methods to application code so that applications can log messages at runtime. Second, logger objects determine which log messages to act upon based upon severity (the default filtering facility) or filter objects. Third, logger objects pass along relevant log messages to all interested log handlers.

The most widely used methods on logger objects fall into two categories: configuration and message sending.

These are the most common configuration methods:

- `Logger.setLevel()` specifies the lowest-severity log message a logger will handle, where `debug` is the lowest built-in severity level and `critical` is the highest built-in severity. For example, if the severity level is `INFO`, the logger will handle only `INFO`, `WARNING`, `ERROR`, and `CRITICAL` messages and will ignore `DEBUG` messages.
- `Logger.addHandler()` and `Logger.removeHandler()` add and remove handler objects from the logger object. Handlers are covered in more detail in *Handlers*.
- `Logger.addFilter()` and `Logger.removeFilter()` add and remove filter objects from the logger object. Filters are covered in more detail in *filter*.

You don't need to always call these methods on every logger you create. See the last two paragraphs in this section.

With the logger object configured, the following methods create log messages:

- `Logger.debug()`, `Logger.info()`, `Logger.warning()`, `Logger.error()`, and `Logger.critical()` all create log records with a message and a level that corresponds to their respective method names. The message is actually a format string, which may contain the standard string substitution syntax of `%s`, `%d`, `%f`, and so on. The rest of their arguments is a list of objects that correspond with the substitution fields in the message. With regard to `**kwargs`, the logging methods care only about a keyword of `exc_info` and use it to determine whether to log exception information.
- `Logger.exception()` creates a log message similar to `Logger.error()`. The difference is that `Logger.exception()` dumps a stack trace along with it. Call this method only from an exception handler.
- `Logger.log()` takes a log level as an explicit argument. This is a little more verbose for logging messages than using the log level convenience methods listed above, but this is how to log at custom log levels.

`getLogger()` returns a reference to a logger instance with the specified name if it is provided, or `root` if not. The names are period-separated hierarchical structures. Multiple calls to `getLogger()` with the same name will return a reference to the same logger object. Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of `foo`, loggers with names of `foo.bar`, `foo.bar.baz`, and `foo.bam` are all descendants of `foo`.

Loggers have a concept of *effective level*. If a level is not explicitly set on a logger, the level of its parent is used instead as its effective level. If the parent has no explicit level set, its parent is examined, and so on - all ancestors are searched until an explicitly set level is found. The root logger always has an explicit level set (`WARNING` by default). When deciding whether to process an event, the effective level of the logger is used to determine whether the event is passed to the logger's handlers.

Child loggers propagate messages up to the handlers associated with their ancestor loggers. Because of this, it is unnecessary to define and configure handlers for all the loggers an application uses. It is sufficient to configure handlers for a top-level logger and create child loggers as needed. (You can, however, turn off propagation by setting the *propagate* attribute of a logger to *False*.)

## 2.2 Handlers

Handler objects are responsible for dispatching the appropriate log messages (based on the log messages' severity) to the handler's specified destination. Logger objects can add zero or more handler objects to themselves with an `addHandler()` method. As an example scenario, an application may want to send all log messages to a log file, all log messages of error or higher to stdout, and all messages of critical to an email address. This scenario requires three individual handlers where each handler is responsible for sending messages of a specific severity to a specific location.

The standard library includes quite a few handler types (see *Useful Handlers*); the tutorials use mainly `StreamHandler` and `FileHandler` in its examples.

There are very few methods in a handler for application developers to concern themselves with. The only handler methods that seem relevant for application developers who are using the built-in handler objects (that is, not creating custom handlers) are the following configuration methods:

- The `Handler.setLevel()` method, just as in logger objects, specifies the lowest severity that will be dispatched to the appropriate destination. Why are there two `setLevel()` methods? The level set in the logger determines which severity of messages it will pass to its handlers. The level set in each handler determines which messages that handler will send on.
- `setFormatter()` selects a `Formatter` object for this handler to use.
- `addFilter()` and `removeFilter()` respectively configure and deconfigure filter objects on handlers.

Application code should not directly instantiate and use instances of `Handler`. Instead, the `Handler` class is a base class that defines the interface that all handlers should have and establishes some default behavior that child classes can use (or override).

## 2.3 Formatters

Formatter objects configure the final order, structure, and contents of the log message. Unlike the base `logging.Handler` class, application code may instantiate formatter classes, although you could likely subclass the formatter if your application needs special behavior. The constructor takes two optional arguments – a message format string and a date format string.

```
logging.Formatter.__init__(fmt=None, datefmt=None)
```

If there is no message format string, the default is to use the raw message. If there is no date format string, the default date format is:

```
%Y-%m-%d %H:%M:%S
```

with the milliseconds tacked on at the end.

The message format string uses `%(dictionary key)s` styled string substitution; the possible keys are documented in *logrecord-attributes*.

The following message format string will log the time in a human-readable format, the severity of the message, and the contents of the message, in that order:

```
'%(asctime)s - %(levelname)s - %(message)s'
```

Formatters use a user-configurable function to convert the creation time of a record to a tuple. By default, `time.localtime()` is used; to change this for a particular formatter instance, set the `converter` attribute of the instance to a function with the same signature as `time.localtime()` or `time.gmtime()`. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the `converter` attribute in the `Formatter` class (to `time.gmtime` for GMT display).

## 2.4 Configuring Logging

Programmers can configure logging in three ways:

1. Creating loggers, handlers, and formatters explicitly using Python code that calls the configuration methods listed above.
2. Creating a logging config file and reading it using the `fileConfig()` function.
3. Creating a dictionary of configuration information and passing it to the `dictConfig()` function.

For the reference documentation on the last two options, see *logging-config-api*. The following example configures a very simple logger, a console handler, and a simple formatter using Python code:

```
import logging

# create logger
logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)

# create console handler and set level to debug
ch = logging.StreamHandler()
ch.setLevel(logging.DEBUG)

# create formatter
```

```

formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')

# add formatter to ch
ch.setFormatter(formatter)

# add ch to logger
logger.addHandler(ch)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')

```

Running this module from the command line produces the following output:

```

$ python simple_logging_module.py
2005-03-19 15:10:26,618 - simple_example - DEBUG - debug message
2005-03-19 15:10:26,620 - simple_example - INFO - info message
2005-03-19 15:10:26,695 - simple_example - WARNING - warn message
2005-03-19 15:10:26,697 - simple_example - ERROR - error message
2005-03-19 15:10:26,773 - simple_example - CRITICAL - critical message

```

The following Python module creates a logger, handler, and formatter nearly identical to those in the example listed above, with the only difference being the names of the objects:

```

import logging
import logging.config

logging.config.fileConfig('logging.conf')

# create logger
logger = logging.getLogger('simpleExample')

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')

```

Here is the logging.conf file:

```

[loggers]
keys=root,simpleExample

[handlers]
keys=consoleHandler

[formatters]
keys=simpleFormatter

[logger_root]
level=DEBUG
handlers=consoleHandler

```

```

[logger_simpleExample]
level=DEBUG
handlers=consoleHandler
qualname=simpleExample
propagate=0

[handler_consoleHandler]
class=StreamHandler
level=DEBUG
formatter=simpleFormatter
args=(sys.stdout,)

[formatter_simpleFormatter]
format=%(asctime)s - %(name)s - %(levelname)s - %(message)s
datefmt=

```

The output is nearly identical to that of the non-config-file-based example:

```

$ python simple_logging_config.py
2005-03-19 15:38:55,977 - simpleExample - DEBUG - debug message
2005-03-19 15:38:55,979 - simpleExample - INFO - info message
2005-03-19 15:38:56,054 - simpleExample - WARNING - warn message
2005-03-19 15:38:56,055 - simpleExample - ERROR - error message
2005-03-19 15:38:56,130 - simpleExample - CRITICAL - critical message

```

You can see that the config file approach has a few advantages over the Python code approach, mainly separation of configuration and code and the ability of noncoders to easily modify the logging properties.

**Warning:** The `fileConfig()` function takes a default parameter, `disable_existing_loggers`, which defaults to `True` for reasons of backward compatibility. This may or may not be what you want, since it will cause any loggers existing before the `fileConfig()` call to be disabled unless they (or an ancestor) are explicitly named in the configuration. Please refer to the reference documentation for more information, and specify `False` for this parameter if you wish.

The dictionary passed to `dictConfig()` can also specify a Boolean value with key `disable_existing_loggers`, which if not specified explicitly in the dictionary also defaults to being interpreted as `True`. This leads to the logger-disabling behaviour described above, which may not be what you want - in which case, provide the key explicitly with a value of `False`.

Note that the class names referenced in config files need to be either relative to the logging module, or absolute values which can be resolved using normal import mechanisms. Thus, you could use either `WatchedFileHandler` (relative to the logging module) or `mypackage.mymodule.MyHandler` (for a class defined in package `mypackage` and module `mymodule`, where `mypackage` is available on the Python import path).

In Python 2.7, a new means of configuring logging has been introduced, using dictionaries to hold configuration information. This provides a superset of the functionality of the config-file-based approach outlined above, and is the recommended configuration method for new applications and deployments. Because a Python dictionary is used to hold configuration information, and since you can populate that dictionary using different means, you have more options for configuration. For example, you can use a configuration file in JSON format, or, if you have access to YAML processing functionality, a file in YAML format, to populate the configuration dictionary. Or, of course, you can construct the dictionary in Python code, receive it in pickled form over a socket, or use whatever approach makes sense for your application.

Here's an example of the same configuration as above, in YAML format for the new dictionary-based approach:

```

version: 1
formatters:
  simple:

```

```

    format: '%(asctime)s - %(name)s - %(levelname)s - %(message)s'
handlers:
  console:
    class: logging.StreamHandler
    level: DEBUG
    formatter: simple
    stream: ext://sys.stdout
loggers:
  simpleExample:
    level: DEBUG
    handlers: [console]
    propagate: no
root:
  level: DEBUG
  handlers: [console]

```

For more information about logging using a dictionary, see *logging-config-api*.

## 2.5 What happens if no configuration is provided

If no logging configuration is provided, it is possible to have a situation where a logging event needs to be output, but no handlers can be found to output the event. The behaviour of the logging package in these circumstances is dependent on the Python version.

For Python 2.x, the behaviour is as follows:

- If *logging.raiseExceptions* is *False* (production mode), the event is silently dropped.
- If *logging.raiseExceptions* is *True* (development mode), a message 'No handlers could be found for logger X.Y.Z' is printed once.

## 2.6 Configuring Logging for a Library

When developing a library which uses logging, you should take care to document how the library uses logging - for example, the names of loggers used. Some consideration also needs to be given to its logging configuration. If the using application does not use logging, and library code makes logging calls, then (as described in the previous section) events of severity `WARNING` and greater will be printed to `sys.stderr`. This is regarded as the best default behaviour.

If for some reason you *don't* want these messages printed in the absence of any logging configuration, you can attach a do-nothing handler to the top-level logger for your library. This avoids the message being printed, since a handler will be always be found for the library's events: it just doesn't produce any output. If the library user configures logging for application use, presumably that configuration will add some handlers, and if levels are suitably configured then logging calls made in library code will send output to those handlers, as normal.

A do-nothing handler is included in the logging package: `NullHandler` (since Python 2.7). An instance of this handler could be added to the top-level logger of the logging namespace used by the library (*if* you want to prevent your library's logged events being output to `sys.stderr` in the absence of logging configuration). If all logging by a library *foo* is done using loggers with names matching 'foo.x', 'foo.x.y', etc. then the code:

```

import logging
logging.getLogger('foo').addHandler(logging.NullHandler())

```

should have the desired effect. If an organisation produces a number of libraries, then the logger name specified can be 'orgname.foo' rather than just 'foo'.

**PLEASE NOTE:** It is strongly advised that you *do not add any handlers other than* `NullHandler` *to your library's loggers*. This is because the configuration of handlers is the prerogative of the application developer who uses your library. The application developer knows their target audience and what handlers are most appropriate for their application: if you add handlers 'under the hood', you might well interfere with their ability to carry out unit tests and deliver logs which suit their requirements.

## 3 Logging Levels

The numeric values of logging levels are given in the following table. These are primarily of interest if you want to define your own levels, and need them to have specific values relative to the predefined levels. If you define a level with the same numeric value, it overwrites the predefined value; the predefined name is lost.

Level	Numeric value
CRITICAL	50
ERROR	40
WARNING	30
INFO	20
DEBUG	10
NOTSET	0

Levels can also be associated with loggers, being set either by the developer or through loading a saved logging configuration. When a logging method is called on a logger, the logger compares its own level with the level associated with the method call. If the logger's level is higher than the method call's, no logging message is actually generated. This is the basic mechanism controlling the verbosity of logging output.

Logging messages are encoded as instances of the `LogRecord` class. When a logger decides to actually log an event, a `LogRecord` instance is created from the logging message.

Logging messages are subjected to a dispatch mechanism through the use of *handlers*, which are instances of subclasses of the `Handler` class. Handlers are responsible for ensuring that a logged message (in the form of a `LogRecord`) ends up in a particular location (or set of locations) which is useful for the target audience for that message (such as end users, support desk staff, system administrators, developers). Handlers are passed `LogRecord` instances intended for particular destinations. Each logger can have zero, one or more handlers associated with it (via the `addHandler()` method of `Logger`). In addition to any handlers directly associated with a logger, *all handlers associated with all ancestors of the logger* are called to dispatch the message (unless the *propagate* flag for a logger is set to a false value, at which point the passing to ancestor handlers stops).

Just as for loggers, handlers can have levels associated with them. A handler's level acts as a filter in the same way as a logger's level does. If a handler decides to actually dispatch an event, the `emit()` method is used to send the message to its destination. Most user-defined subclasses of `Handler` will need to override this `emit()`.

### 3.1 Custom Levels

Defining your own levels is possible, but should not be necessary, as the existing levels have been chosen on the basis of practical experience. However, if you are convinced that you need custom levels, great care should be exercised when doing this, and it is possibly *a very bad idea to define custom levels if you are developing a library*. That's because if multiple library authors all define their own custom levels, there is a chance that the logging output from such multiple libraries used together will be difficult for the using developer to control and/or interpret, because a given numeric value might mean different things for different libraries.

## 4 Useful Handlers

In addition to the base `Handler` class, many useful subclasses are provided:

1. `StreamHandler` instances send messages to streams (file-like objects).
2. `FileHandler` instances send messages to disk files.
3. `BaseRotatingHandler` is the base class for handlers that rotate log files at a certain point. It is not meant to be instantiated directly. Instead, use `RotatingFileHandler` or `TimedRotatingFileHandler`.
4. `RotatingFileHandler` instances send messages to disk files, with support for maximum log file sizes and log file rotation.
5. `TimedRotatingFileHandler` instances send messages to disk files, rotating the log file at certain timed intervals.
6. `SocketHandler` instances send messages to TCP/IP sockets.
7. `DatagramHandler` instances send messages to UDP sockets.
8. `SMTPHandler` instances send messages to a designated email address.
9. `SysLogHandler` instances send messages to a Unix syslog daemon, possibly on a remote machine.
10. `NTEventLogHandler` instances send messages to a Windows NT/2000/XP event log.
11. `MemoryHandler` instances send messages to a buffer in memory, which is flushed whenever specific criteria are met.
12. `HTTPHandler` instances send messages to an HTTP server using either GET or POST semantics.
13. `WatchedFileHandler` instances watch the file they are logging to. If the file changes, it is closed and reopened using the file name. This handler is only useful on Unix-like systems; Windows does not support the underlying mechanism used.
14. `NullHandler` instances do nothing with error messages. They are used by library developers who want to use logging, but want to avoid the 'No handlers could be found for logger XXX' message which can be displayed if the library user has not configured logging. See *Configuring Logging for a Library* for more information.

New in version 2.7: The `NullHandler` class. The `NullHandler`, `StreamHandler` and `FileHandler` classes are defined in the core logging package. The other handlers are defined in a sub-module, `logging.handlers`. (There is also another sub-module, `logging.config`, for configuration functionality.)

Logged messages are formatted for presentation through instances of the `Formatter` class. They are initialized with a format string suitable for use with the `%` operator and a dictionary.

For formatting multiple messages in a batch, instances of `BufferingFormatter` can be used. In addition to the format string (which is applied to each message in the batch), there is provision for header and trailer format strings.

When filtering based on logger level and/or handler level is not enough, instances of `Filter` can be added to both `Logger` and `Handler` instances (through their `addFilter()` method). Before deciding to process a message further, both loggers and handlers consult all their filters for permission. If any filter returns a false value, the message is not processed further.

The basic `Filter` functionality allows filtering by specific logger name. If this feature is used, messages sent to the named logger and its children are allowed through the filter, and all others dropped.

## 5 Exceptions raised during logging

The logging package is designed to swallow exceptions which occur while logging in production. This is so that errors which occur while handling logging events - such as logging misconfiguration, network or other similar errors - do not cause the application using logging to terminate prematurely.

`SystemExit` and `KeyboardInterrupt` exceptions are never swallowed. Other exceptions which occur during the `emit()` method of a `Handler` subclass are passed to its `handleError()` method.

The default implementation of `handleError()` in `Handler` checks to see if a module-level variable, `raiseExceptions`, is set. If set, a traceback is printed to `sys.stderr`. If not set, the exception is swallowed.

**Note:** The default value of `raiseExceptions` is `True`. This is because during development, you typically want to be notified of any exceptions that occur. It's advised that you set `raiseExceptions` to `False` for production usage.

## 6 Using arbitrary objects as messages

In the preceding sections and examples, it has been assumed that the message passed when logging the event is a string. However, this is not the only possibility. You can pass an arbitrary object as a message, and its `__str__()` method will be called when the logging system needs to convert it to a string representation. In fact, if you want to, you can avoid computing a string representation altogether - for example, the `SocketHandler` emits an event by pickling it and sending it over the wire.

## 7 Optimization

Formatting of message arguments is deferred until it cannot be avoided. However, computing the arguments passed to the logging method can also be expensive, and you may want to avoid doing it if the logger will just throw away your event. To decide what to do, you can call the `isEnabledFor()` method which takes a level argument and returns true if the event would be created by the `Logger` for that level of call. You can write code like this:

```
if logger.isEnabledFor(logging.DEBUG):
    logger.debug('Message with %s, %s', expensive_func1(),
                expensive_func2())
```

so that if the logger's threshold is set above `DEBUG`, the calls to `expensive_func1()` and `expensive_func2()` are never made.

There are other optimizations which can be made for specific applications which need more precise control over what logging information is collected. Here's a list of things you can do to avoid processing during logging which you don't need:

What you don't want to collect	How to avoid collecting it
Information about where calls were made from.	Set <code>logging._srcfile</code> to <code>None</code> .
Threading information.	Set <code>logging.logThreads</code> to <code>0</code> .
Process information.	Set <code>logging.logProcesses</code> to <code>0</code> .

Also note that the core logging module only includes the basic handlers. If you don't import `logging.handlers` and `logging.config`, they won't take up any memory.

**See Also:**

**Module `logging`** API reference for the logging module.

**Module `logging.config`** Configuration API for the logging module.

**Module logging.handlers** Useful handlers included with the logging module.

*A logging cookbook*



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### Symbols

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# Logging Cookbook

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Vinay Sajip <vinay\_sajip at red-dove dot com>

This page contains a number of recipes related to logging, which have been found useful in the past.

## 1 Using logging in multiple modules

Multiple calls to `logging.getLogger('someLogger')` return a reference to the same logger object. This is true not only within the same module, but also across modules as long as it is in the same Python interpreter process.

It is true for references to the same object; additionally, application code can define and configure a parent logger in one module and create (but not configure) a child logger in a separate module, and all logger calls to the child will pass up to the parent. Here is a main module:

```
import logging
import auxiliary_module

# create logger with 'spam_application'
logger = logging.getLogger('spam_application')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
fh.setFormatter(formatter)
ch.setFormatter(formatter)
# add the handlers to the logger
logger.addHandler(fh)
logger.addHandler(ch)

logger.info('creating an instance of auxiliary_module.Auxiliary')
a = auxiliary_module.Auxiliary()
logger.info('created an instance of auxiliary_module.Auxiliary')
logger.info('calling auxiliary_module.Auxiliary.do_something()')
a.do_something()
logger.info('finished auxiliary_module.Auxiliary.do_something()')
logger.info('calling auxiliary_module.some_function()')
auxiliary_module.some_function()
logger.info('done with auxiliary_module.some_function()')
```

Here is the auxiliary module:

```
import logging

# create logger
module_logger = logging.getLogger('spam_application.auxiliary')

class Auxiliary:
    def __init__(self):
        self.logger = logging.getLogger('spam_application.auxiliary.Auxiliary')
        self.logger.info('creating an instance of Auxiliary')
    def do_something(self):
        self.logger.info('doing something')
        a = 1 + 1
        self.logger.info('done doing something')

def some_function():
    module_logger.info('received a call to "some_function"')
```

The output looks like this:

```

2005-03-23 23:47:11,663 - spam_application - INFO -
    creating an instance of auxiliary_module.Auxiliary
2005-03-23 23:47:11,665 - spam_application.auxiliary.Auxiliary - INFO -
    creating an instance of Auxiliary
2005-03-23 23:47:11,665 - spam_application - INFO -
    created an instance of auxiliary_module.Auxiliary
2005-03-23 23:47:11,668 - spam_application - INFO -
    calling auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,668 - spam_application.auxiliary.Auxiliary - INFO -
    doing something
2005-03-23 23:47:11,669 - spam_application.auxiliary.Auxiliary - INFO -
    done doing something
2005-03-23 23:47:11,670 - spam_application - INFO -
    finished auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,671 - spam_application - INFO -
    calling auxiliary_module.some_function()
2005-03-23 23:47:11,672 - spam_application.auxiliary - INFO -
    received a call to 'some_function'
2005-03-23 23:47:11,673 - spam_application - INFO -
    done with auxiliary_module.some_function()

```

## 2 Multiple handlers and formatters

Loggers are plain Python objects. The `addHandler()` method has no minimum or maximum quota for the number of handlers you may add. Sometimes it will be beneficial for an application to log all messages of all severities to a text file while simultaneously logging errors or above to the console. To set this up, simply configure the appropriate handlers. The logging calls in the application code will remain unchanged. Here is a slight modification to the previous simple module-based configuration example:

```
import logging
```

```

logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
ch.setFormatter(formatter)
fh.setFormatter(formatter)
# add the handlers to logger
logger.addHandler(ch)
logger.addHandler(fh)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')

```

Notice that the ‘application’ code does not care about multiple handlers. All that changed was the addition and configuration of a new handler named *fh*.

The ability to create new handlers with higher- or lower-severity filters can be very helpful when writing and testing an application. Instead of using many `print` statements for debugging, use `logger.debug`: Unlike the `print` statements, which you will have to delete or comment out later, the `logger.debug` statements can remain intact in the source code and remain dormant until you need them again. At that time, the only change that needs to happen is to modify the severity level of the logger and/or handler to debug.

### 3 Logging to multiple destinations

Let’s say you want to log to console and file with different message formats and in differing circumstances. Say you want to log messages with levels of `DEBUG` and higher to file, and those messages at level `INFO` and higher to the console. Let’s also assume that the file should contain timestamps, but the console messages should not. Here’s how you can achieve this:

```
import logging

# set up logging to file - see previous section for more details
logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s %(name)-12s %(levelname)-8s %(message)s',
                    datefmt='%m-%d %H:%M',
                    filename='/temp/myapp.log',
                    filemode='w')

# define a Handler which writes INFO messages or higher to the sys.stderr
console = logging.StreamHandler()
console.setLevel(logging.INFO)
# set a format which is simpler for console use
formatter = logging.Formatter('%(name)-12s: %(levelname)-8s %(message)s')
# tell the handler to use this format
console.setFormatter(formatter)
# add the handler to the root logger
logging.getLogger('').addHandler(console)

# Now, we can log to the root logger, or any other logger. First the root...
logging.info('Jackdaws love my big sphinx of quartz.')

# Now, define a couple of other loggers which might represent areas in your
# application:

logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')

logger1.debug('Quick zephyrs blow, vexing daft Jim.')
logger1.info('How quickly daft jumping zebras vex.')
logger2.warning('Jail zesty vixen who grabbed pay from quack.')
logger2.error('The five boxing wizards jump quickly.')
```

When you run this, on the console you will see

```
root          : INFO      Jackdaws love my big sphinx of quartz.
myapp.area1   : INFO      How quickly daft jumping zebras vex.
myapp.area2   : WARNING   Jail zesty vixen who grabbed pay from quack.
myapp.area2   : ERROR     The five boxing wizards jump quickly.
```

and in the file you will see something like

```
10-22 22:19 root          INFO      Jackdaws love my big sphinx of quartz.
10-22 22:19 myapp.area1    DEBUG    Quick zephyrs blow, vexing daft Jim.
10-22 22:19 myapp.area1    INFO     How quickly daft jumping zebras vex.
10-22 22:19 myapp.area2    WARNING  Jail zesty vixen who grabbed pay from quack.
10-22 22:19 myapp.area2    ERROR    The five boxing wizards jump quickly.
```

As you can see, the DEBUG message only shows up in the file. The other messages are sent to both destinations.

This example uses console and file handlers, but you can use any number and combination of handlers you choose.

## 4 Configuration server example

Here is an example of a module using the logging configuration server:

```
import logging
import logging.config
import time
import os

# read initial config file
logging.config.fileConfig('logging.conf')

# create and start listener on port 9999
t = logging.config.listen(9999)
t.start()

logger = logging.getLogger('simpleExample')

try:
    # loop through logging calls to see the difference
    # new configurations make, until Ctrl+C is pressed
    while True:
        logger.debug('debug message')
        logger.info('info message')
        logger.warn('warn message')
        logger.error('error message')
        logger.critical('critical message')
        time.sleep(5)
except KeyboardInterrupt:
    # cleanup
    logging.config.stopListening()
    t.join()
```

And here is a script that takes a filename and sends that file to the server, properly preceded with the binary-encoded length, as the new logging configuration:

```
#!/usr/bin/env python
import socket, sys, struct

with open(sys.argv[1], 'rb') as f:
    data_to_send = f.read()

HOST = 'localhost'
```

```

PORT = 9999
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
print('connecting...')
s.connect((HOST, PORT))
print('sending config...')
s.send(struct.pack('>L', len(data_to_send)))
s.send(data_to_send)
s.close()
print('complete')

```

## 5 Sending and receiving logging events across a network

Let's say you want to send logging events across a network, and handle them at the receiving end. A simple way of doing this is attaching a `SocketHandler` instance to the root logger at the sending end:

```

import logging, logging.handlers

rootLogger = logging.getLogger('')
rootLogger.setLevel(logging.DEBUG)
socketHandler = logging.handlers.SocketHandler('localhost',
                                               logging.handlers.DEFAULT_TCP_LOGGING_PORT)
# don't bother with a formatter, since a socket handler sends the event as
# an unformatted pickle
rootLogger.addHandler(socketHandler)

# Now, we can log to the root logger, or any other logger. First the root...
logging.info('Jackdaws love my big sphinx of quartz.')

# Now, define a couple of other loggers which might represent areas in your
# application:

logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')

logger1.debug('Quick zephyrs blow, vexing daft Jim.')
logger1.info('How quickly daft jumping zebras vex.')
logger2.warning('Jail zesty vixen who grabbed pay from quack.')
logger2.error('The five boxing wizards jump quickly.')

```

At the receiving end, you can set up a receiver using the `SocketServer` module. Here is a basic working example:

```

import pickle
import logging
import logging.handlers
import SocketServer
import struct

class LogRecordStreamHandler(SocketServer.StreamRequestHandler):
    """Handler for a streaming logging request.

    This basically logs the record using whatever logging policy is
    configured locally.
    """

```

```

def handle(self):
    """
    Handle multiple requests - each expected to be a 4-byte length,
    followed by the LogRecord in pickle format. Logs the record
    according to whatever policy is configured locally.
    """
    while True:
        chunk = self.connection.recv(4)
        if len(chunk) < 4:
            break
        slen = struct.unpack('>L', chunk)[0]
        chunk = self.connection.recv(slen)
        while len(chunk) < slen:
            chunk = chunk + self.connection.recv(slen - len(chunk))
        obj = self.unPickle(chunk)
        record = logging.makeLogRecord(obj)
        self.handleLogRecord(record)

def unPickle(self, data):
    return pickle.loads(data)

def handleLogRecord(self, record):
    # if a name is specified, we use the named logger rather than the one
    # implied by the record.
    if self.server.logname is not None:
        name = self.server.logname
    else:
        name = record.name
    logger = logging.getLogger(name)
    # N.B. EVERY record gets logged. This is because Logger.handle
    # is normally called AFTER logger-level filtering. If you want
    # to do filtering, do it at the client end to save wasting
    # cycles and network bandwidth!
    logger.handle(record)

class LogRecordSocketReceiver(SocketServer.ThreadingTCPServer):
    """
    Simple TCP socket-based logging receiver suitable for testing.
    """

    allow_reuse_address = 1

    def __init__(self, host='localhost',
                 port=logging.handlers.DEFAULT_TCP_LOGGING_PORT,
                 handler=LogRecordStreamHandler):
        SocketServer.ThreadingTCPServer.__init__(self, (host, port), handler)
        self.abort = 0
        self.timeout = 1
        self.logname = None

    def serve_until_stopped(self):
        import select
        abort = 0

```

```

while not abort:
    rd, wr, ex = select.select([self.socket.fileno()],
                               [], [],
                               self.timeout)

    if rd:
        self.handle_request()
        abort = self.abort

def main():
    logging.basicConfig(
        format='%(relativeCreated)5d %(name)-15s %(levelname)-8s %(message)s')
    tcpserver = LogRecordSocketReceiver()
    print('About to start TCP server...')
    tcpserver.serve_until_stopped()

if __name__ == '__main__':
    main()

```

First run the server, and then the client. On the client side, nothing is printed on the console; on the server side, you should see something like:

```

About to start TCP server...
59 root          INFO      Jackdaws love my big sphinx of quartz.
59 myapp.area1   DEBUG    Quick zephyrs blow, vexing daft Jim.
69 myapp.area1   INFO     How quickly daft jumping zebras vex.
69 myapp.area2   WARNING  Jail zesty vixen who grabbed pay from quack.
69 myapp.area2   ERROR    The five boxing wizards jump quickly.

```

Note that there are some security issues with pickle in some scenarios. If these affect you, you can use an alternative serialization scheme by overriding the `makePickle()` method and implementing your alternative there, as well as adapting the above script to use your alternative serialization.

## 6 Adding contextual information to your logging output

Sometimes you want logging output to contain contextual information in addition to the parameters passed to the logging call. For example, in a networked application, it may be desirable to log client-specific information in the log (e.g. remote client's username, or IP address). Although you could use the *extra* parameter to achieve this, it's not always convenient to pass the information in this way. While it might be tempting to create `Logger` instances on a per-connection basis, this is not a good idea because these instances are not garbage collected. While this is not a problem in practice, when the number of `Logger` instances is dependent on the level of granularity you want to use in logging an application, it could be hard to manage if the number of `Logger` instances becomes effectively unbounded.

### 6.1 Using `LoggerAdapters` to impart contextual information

An easy way in which you can pass contextual information to be output along with logging event information is to use the `LoggerAdapter` class. This class is designed to look like a `Logger`, so that you can call `debug()`, `info()`, `warning()`, `error()`, `exception()`, `critical()` and `log()`. These methods have the same signatures as their counterparts in `Logger`, so you can use the two types of instances interchangeably.

When you create an instance of `LoggerAdapter`, you pass it a `Logger` instance and a dict-like object which contains your contextual information. When you call one of the logging methods on an instance of `LoggerAdapter`,

it delegates the call to the underlying instance of `Logger` passed to its constructor, and arranges to pass the contextual information in the delegated call. Here's a snippet from the code of `LoggerAdapter`:

```
def debug(self, msg, *args, **kwargs):
    """
    Delegate a debug call to the underlying logger, after adding
    contextual information from this adapter instance.
    """
    msg, kwargs = self.process(msg, kwargs)
    self.logger.debug(msg, *args, **kwargs)
```

The `process()` method of `LoggerAdapter` is where the contextual information is added to the logging output. It's passed the message and keyword arguments of the logging call, and it passes back (potentially) modified versions of these to use in the call to the underlying logger. The default implementation of this method leaves the message alone, but inserts an 'extra' key in the keyword argument whose value is the dict-like object passed to the constructor. Of course, if you had passed an 'extra' keyword argument in the call to the adapter, it will be silently overwritten.

The advantage of using 'extra' is that the values in the dict-like object are merged into the `LogRecord` instance's `__dict__`, allowing you to use customized strings with your `Formatter` instances which know about the keys of the dict-like object. If you need a different method, e.g. if you want to prepend or append the contextual information to the message string, you just need to subclass `LoggerAdapter` and override `process()` to do what you need. Here's an example script which uses this class, which also illustrates what dict-like behaviour is needed from an arbitrary 'dict-like' object for use in the constructor:

```
import logging
```

```
class ConnInfo:
```

```
    """
    An example class which shows how an arbitrary class can be used as
    the 'extra' context information repository passed to a LoggerAdapter.
    """
```

```
    def __getitem__(self, name):
        """
        To allow this instance to look like a dict.
        """
        from random import choice
        if name == 'ip':
            result = choice(['127.0.0.1', '192.168.0.1'])
        elif name == 'user':
            result = choice(['jim', 'fred', 'sheila'])
        else:
            result = self.__dict__.get(name, '?')
        return result
```

```
    def __iter__(self):
        """
        To allow iteration over keys, which will be merged into
        the LogRecord dict before formatting and output.
        """
        keys = ['ip', 'user']
        keys.extend(self.__dict__.keys())
        return keys.__iter__()
```

```
if __name__ == '__main__':
    from random import choice
```

```

levels = (logging.DEBUG, logging.INFO, logging.WARNING, logging.ERROR, logging.CRITICAL)
a1 = logging.LoggerAdapter(logging.getLogger('a.b.c'),
                           { 'ip' : '123.231.231.123', 'user' : 'sheila' })
logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)-15s %(name)-5s %(levelname)-8s IP: %(ip)-15s User: %(user)-15s',
                    datefmt='%Y-%m-%d %H:%M:%S')
a1.debug('A debug message')
a1.info('An info message with %s', 'some parameters')
a2 = logging.LoggerAdapter(logging.getLogger('d.e.f'), ConnInfo())
for x in range(10):
    lvl = choice(levels)
    lvlname = logging.getLevelName(lvl)
    a2.log(lvl, 'A message at %s level with %d %s', lvlname, 2, 'parameters')

```

When this script is run, the output should look something like this:

```

2008-01-18 14:49:54,023 a.b.c DEBUG      IP: 123.231.231.123 User: sheila   A debug message
2008-01-18 14:49:54,023 a.b.c INFO      IP: 123.231.231.123 User: sheila   An info message v
2008-01-18 14:49:54,023 d.e.f CRITICAL  IP: 192.168.0.1   User: jim     A message at CRI
2008-01-18 14:49:54,033 d.e.f INFO      IP: 192.168.0.1   User: jim     A message at INFO
2008-01-18 14:49:54,033 d.e.f WARNING   IP: 192.168.0.1   User: sheila  A message at WARI
2008-01-18 14:49:54,033 d.e.f ERROR     IP: 127.0.0.1     User: fred    A message at ERRO
2008-01-18 14:49:54,033 d.e.f ERROR     IP: 127.0.0.1     User: sheila  A message at ERRO
2008-01-18 14:49:54,033 d.e.f WARNING   IP: 192.168.0.1   User: sheila  A message at WARI
2008-01-18 14:49:54,033 d.e.f WARNING   IP: 192.168.0.1   User: jim     A message at WARI
2008-01-18 14:49:54,033 d.e.f INFO      IP: 192.168.0.1   User: fred    A message at INFO
2008-01-18 14:49:54,033 d.e.f WARNING   IP: 192.168.0.1   User: sheila  A message at WARI
2008-01-18 14:49:54,033 d.e.f WARNING   IP: 127.0.0.1     User: jim     A message at WARI

```

## 6.2 Using Filters to impart contextual information

You can also add contextual information to log output using a user-defined `Filter`. `Filter` instances are allowed to modify the `LogRecords` passed to them, including adding additional attributes which can then be output using a suitable format string, or if needed a custom `Formatter`.

For example in a web application, the request being processed (or at least, the interesting parts of it) can be stored in a `threadlocal` (`threading.local`) variable, and then accessed from a `Filter` to add, say, information from the request - say, the remote IP address and remote user's username - to the `LogRecord`, using the attribute names 'ip' and 'user' as in the `LoggerAdapter` example above. In that case, the same format string can be used to get similar output to that shown above. Here's an example script:

```

import logging
from random import choice

class ContextFilter(logging.Filter):
    """
    This is a filter which injects contextual information into the log.

    Rather than use actual contextual information, we just use random
    data in this demo.
    """

    USERS = ['jim', 'fred', 'sheila']
    IPS = ['123.231.231.123', '127.0.0.1', '192.168.0.1']

    def filter(self, record):

```

```

        record.ip = choice(ContextFilter.IPS)
        record.user = choice(ContextFilter.USERS)
        return True

if __name__ == '__main__':
    levels = (logging.DEBUG, logging.INFO, logging.WARNING, logging.ERROR, logging.CRITICAL)
    logging.basicConfig(level=logging.DEBUG,
                        format='%(asctime)-15s %(name)-5s %(levelname)-8s IP: %(ip)-15s User: %(user)-15s',
                        datefmt='%Y-%m-%d %H:%M:%S')
    a1 = logging.getLogger('a.b.c')
    a2 = logging.getLogger('d.e.f')

    f = ContextFilter()
    a1.addFilter(f)
    a2.addFilter(f)
    a1.debug('A debug message')
    a1.info('An info message with %s', 'some parameters')
    for x in range(10):
        lvl = choice(levels)
        lvlname = logging.getLevelName(lvl)
        a2.log(lvl, 'A message at %s level with %d %s', lvlname, 2, 'parameters')

```

which, when run, produces something like:

```

2010-09-06 22:38:15,292 a.b.c DEBUG      IP: 123.231.231.123 User: fred      A debug message
2010-09-06 22:38:15,300 a.b.c INFO      IP: 192.168.0.1     User: sheila     An info message v
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1      User: sheila     A message at CRI
2010-09-06 22:38:15,300 d.e.f ERROR     IP: 127.0.0.1      User: jim        A message at ERR
2010-09-06 22:38:15,300 d.e.f DEBUG     IP: 127.0.0.1      User: sheila     A message at DEB
2010-09-06 22:38:15,300 d.e.f ERROR     IP: 123.231.231.123 User: fred       A message at ERR
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 192.168.0.1     User: jim        A message at CRI
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1      User: sheila     A message at CRI
2010-09-06 22:38:15,300 d.e.f DEBUG     IP: 192.168.0.1     User: jim        A message at DEB
2010-09-06 22:38:15,301 d.e.f ERROR     IP: 127.0.0.1      User: sheila     A message at ERR
2010-09-06 22:38:15,301 d.e.f DEBUG     IP: 123.231.231.123 User: fred       A message at DEB
2010-09-06 22:38:15,301 d.e.f INFO      IP: 123.231.231.123 User: fred       A message at INF

```

## 7 Logging to a single file from multiple processes

Although logging is thread-safe, and logging to a single file from multiple threads in a single process *is* supported, logging to a single file from *multiple processes* is *not* supported, because there is no standard way to serialize access to a single file across multiple processes in Python. If you need to log to a single file from multiple processes, one way of doing this is to have all the processes log to a `SocketHandler`, and have a separate process which implements a socket server which reads from the socket and logs to file. (If you prefer, you can dedicate one thread in one of the existing processes to perform this function.) *This section* documents this approach in more detail and includes a working socket receiver which can be used as a starting point for you to adapt in your own applications.

If you are using a recent version of Python which includes the `multiprocessing` module, you could write your own handler which uses the `Lock` class from this module to serialize access to the file from your processes. The existing `FileHandler` and subclasses do not make use of `multiprocessing` at present, though they may do so in the future. Note that at present, the `multiprocessing` module does not provide working lock functionality on all platforms (see <http://bugs.python.org/issue3770>).

## 8 Using file rotation

Sometimes you want to let a log file grow to a certain size, then open a new file and log to that. You may want to keep a certain number of these files, and when that many files have been created, rotate the files so that the number of files and the size of the files both remain bounded. For this usage pattern, the logging package provides a `RotatingFileHandler`:

```
import glob
import logging
import logging.handlers

LOG_FILENAME = 'logging_rotatingfile_example.out'

# Set up a specific logger with our desired output level
my_logger = logging.getLogger('MyLogger')
my_logger.setLevel(logging.DEBUG)

# Add the log message handler to the logger
handler = logging.handlers.RotatingFileHandler(
    LOG_FILENAME, maxBytes=20, backupCount=5)

my_logger.addHandler(handler)

# Log some messages
for i in range(20):
    my_logger.debug('i = %d' % i)

# See what files are created
logfiles = glob.glob('%s*' % LOG_FILENAME)

for filename in logfiles:
    print(filename)
```

The result should be 6 separate files, each with part of the log history for the application:

```
logging_rotatingfile_example.out
logging_rotatingfile_example.out.1
logging_rotatingfile_example.out.2
logging_rotatingfile_example.out.3
logging_rotatingfile_example.out.4
logging_rotatingfile_example.out.5
```

The most current file is always `logging_rotatingfile_example.out`, and each time it reaches the size limit it is renamed with the suffix `.1`. Each of the existing backup files is renamed to increment the suffix (`.1` becomes `.2`, etc.) and the `.6` file is erased.

Obviously this example sets the log length much too small as an extreme example. You would want to set `maxBytes` to an appropriate value.

## 9 An example dictionary-based configuration

Below is an example of a logging configuration dictionary - it's taken from the [documentation on the Django project](#). This dictionary is passed to `dictConfig()` to put the configuration into effect:

```

LOGGING = {
    'version': 1,
    'disable_existing_loggers': True,
    'formatters': {
        'verbose': {
            'format': '%(levelname)s %(asctime)s %(module)s %(process)d %(thread)d %(message)s'
        },
        'simple': {
            'format': '%(levelname)s %(message)s'
        },
    },
    'filters': {
        'special': {
            '()': 'project.logging.SpecialFilter',
            'foo': 'bar',
        }
    },
    'handlers': {
        'null': {
            'level': 'DEBUG',
            'class': 'django.utils.log.NullHandler',
        },
        'console': {
            'level': 'DEBUG',
            'class': 'logging.StreamHandler',
            'formatter': 'simple'
        },
        'mail_admins': {
            'level': 'ERROR',
            'class': 'django.utils.log.AdminEmailHandler',
            'filters': ['special']
        }
    },
    'loggers': {
        'django': {
            'handlers': ['null'],
            'propagate': True,
            'level': 'INFO',
        },
        'django.request': {
            'handlers': ['mail_admins'],
            'level': 'ERROR',
            'propagate': False,
        },
        'myproject.custom': {
            'handlers': ['console', 'mail_admins'],
            'level': 'INFO',
            'filters': ['special']
        }
    }
}

```

For more information about this configuration, you can see the [relevant section](#) of the Django documentation.

## 10 Inserting a BOM into messages sent to a SysLogHandler

RFC 5424 requires that a Unicode message be sent to a syslog daemon as a set of bytes which have the following structure: an optional pure-ASCII component, followed by a UTF-8 Byte Order Mark (BOM), followed by Unicode encoded using UTF-8. (See the [relevant section of the specification](#).)

In Python 2.6 and 2.7, code was added to `SysLogHandler` to insert a BOM into the message, but unfortunately, it was implemented incorrectly, with the BOM appearing at the beginning of the message and hence not allowing any pure-ASCII component to appear before it.

As this behaviour is broken, the incorrect BOM insertion code is being removed from Python 2.7.4 and later. However, it is not being replaced, and if you want to produce RFC 5424-compliant messages which include a BOM, an optional pure-ASCII sequence before it and arbitrary Unicode after it, encoded using UTF-8, then you need to do the following:

1. Attach a `Formatter` instance to your `SysLogHandler` instance, with a format string such as:

```
u'ASCII section\ufeffUnicode section'
```

The Unicode code point `u'\feff'`, when encoded using UTF-8, will be encoded as a UTF-8 BOM – the byte-string `'\xef\xbb\xbf'`.

2. Replace the ASCII section with whatever placeholders you like, but make sure that the data that appears in there after substitution is always ASCII (that way, it will remain unchanged after UTF-8 encoding).
3. Replace the Unicode section with whatever placeholders you like; if the data which appears there after substitution contains characters outside the ASCII range, that's fine – it will be encoded using UTF-8.

If the formatted message is Unicode, it *will* be encoded using UTF-8 encoding by `SysLogHandler`. If you follow the above rules, you should be able to produce RFC 5424-compliant messages. If you don't, logging may not complain, but your messages will not be RFC 5424-compliant, and your syslog daemon may complain.

---

# Porting Python 2 Code to Python 3

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**author** Brett Cannon

**Abstract**

With Python 3 being the future of Python while Python 2 is still in active use, it is good to have your project available for both major releases of Python. This guide is meant to help you choose which strategy works best for your project to support both Python 2 & 3 along with how to execute that strategy. If you are looking to port an extension module instead of pure Python code, please see *porting-howto*.

## 1 Choosing a Strategy

When a project makes the decision that it's time to support both Python 2 & 3, a decision needs to be made as to how to go about accomplishing that goal. The chosen strategy will depend on how large the project's existing codebase is and how much divergence you want from your Python 2 codebase from your Python 3 one (e.g., starting a new version with Python 3).

If your project is brand-new or does not have a large codebase, then you may want to consider writing/porting *all of your code for Python 3 and use 3to2* to port your code for Python 2.

If you would prefer to maintain a codebase which is semantically **and** syntactically compatible with Python 2 & 3 simultaneously, you can write *Python 2/3 Compatible Source*. While this tends to lead to somewhat non-idiomatic code, it does mean you keep a rapid development process for you, the developer.

Finally, you do have the option of *using 2to3* to translate Python 2 code into Python 3 code (with some manual help). This can take the form of branching your code and using 2to3 to start a Python 3 branch. You can also have users perform the translation at installation time automatically so that you only have to maintain a Python 2 codebase.

Regardless of which approach you choose, porting is not as hard or time-consuming as you might initially think. You can also tackle the problem piece-meal as a good portion of porting is simply updating your code to follow current best practices in a Python 2/3 compatible way.

### 1.1 Universal Bits of Advice

Regardless of what strategy you pick, there are a few things you should consider.

One is make sure you have a robust test suite. You need to make sure everything continues to work, just like when you support a new minor version of Python. This means making sure your test suite is thorough and is ported properly between Python 2 & 3. You will also most likely want to use something like `tox` to automate testing between both a Python 2 and Python 3 VM.

Two, once your project has Python 3 support, make sure to add the proper classifier on the `Cheeseshop` (PyPI). To have your project listed as Python 3 compatible it must have the `Python 3 classifier` (from <http://techspot.zzzeek.org/2011/01/24/zzzeek-s-guide-to-python-3-porting/>):

```
setup(  
    name='Your Library',  
    version='1.0',
```

```

classifiers=[
    # make sure to use :: Python *and* :: Python :: 3 so
    # that pypi can list the package on the python 3 page
    'Programming Language :: Python',
    'Programming Language :: Python :: 3'
],
packages=['yourlibrary'],
# make sure to add custom_fixers to the MANIFEST.in
include_package_data=True,
# ...
)

```

Doing so will cause your project to show up in the [Python 3 packages list](#). You will know you set the classifier properly as visiting your project page on the Cheeseshop will show a Python 3 logo in the upper-left corner of the page.

Three, the [six](#) project provides a library which helps iron out differences between Python 2 & 3. If you find there is a sticky point that is a continual point of contention in your translation or maintenance of code, consider using a source-compatible solution relying on six. If you have to create your own Python 2/3 compatible solution, you can use `sys.version_info[0] >= 3` as a guard.

Four, read all the approaches. Just because some bit of advice applies to one approach more than another doesn't mean that some advice doesn't apply to other strategies.

Five, drop support for older Python versions if possible. [Python 2.5](#) introduced a lot of useful syntax and libraries which have become idiomatic in Python 3. [Python 2.6](#) introduced future statements which makes compatibility much easier if you are going from Python 2 to 3. [Python 2.7](#) continues the trend in the stdlib. So choose the newest version of Python which you believe can be your minimum support version and work from there.

## 2 Python 3 and 3to2

If you are starting a new project or your codebase is small enough, you may want to consider writing your code for Python 3 and backporting to Python 2 using [3to2](#). Thanks to Python 3 being more strict about things than Python 2 (e.g., bytes vs. strings), the source translation can be easier and more straightforward than from Python 2 to 3. Plus it gives you more direct experience developing in Python 3 which, since it is the future of Python, is a good thing long-term.

A drawback of this approach is that 3to2 is a third-party project. This means that the Python core developers (and thus this guide) can make no promises about how well 3to2 works at any time. There is nothing to suggest, though, that 3to2 is not a high-quality project.

## 3 Python 2 and 2to3

Included with Python since 2.6, the [2to3](#) tool (and `lib2to3` module) helps with porting Python 2 to Python 3 by performing various source translations. This is a perfect solution for projects which wish to branch their Python 3 code from their Python 2 codebase and maintain them as independent codebases. You can even begin preparing to use this approach today by writing future-compatible Python code which works cleanly in Python 2 in conjunction with 2to3; all steps outlined below will work with Python 2 code up to the point when the actual use of 2to3 occurs.

Use of 2to3 as an on-demand translation step at install time is also possible, preventing the need to maintain a separate Python 3 codebase, but this approach does come with some drawbacks. While users will only have to pay the translation cost once at installation, you as a developer will need to pay the cost regularly during development. If your codebase is sufficiently large enough then the translation step ends up acting like a compilation step, robbing you of the rapid development process you are used to with Python. Obviously the time required to translate a project

will vary, so do an experimental translation just to see how long it takes to evaluate whether you prefer this approach compared to using *Python 2/3 Compatible Source* or simply keeping a separate Python 3 codebase.

Below are the typical steps taken by a project which uses a 2to3-based approach to supporting Python 2 & 3.

### 3.1 Support Python 2.7

As a first step, make sure that your project is compatible with **Python 2.7**. This is just good to do as Python 2.7 is the last release of Python 2 and thus will be used for a rather long time. It also allows for use of the `-3` flag to Python to help discover places in your code which 2to3 cannot handle but are known to cause issues.

### 3.2 Try to Support Python 2.6 and Newer Only

While not possible for all projects, if you can support **Python 2.6** and newer **only**, your life will be much easier. Various future statements, `stdlib` additions, etc. exist only in Python 2.6 and later which greatly assist in porting to Python 3. But if your project must keep support for **Python 2.5** (or even **Python 2.4**) then it is still possible to port to Python 3.

Below are the benefits you gain if you only have to support Python 2.6 and newer. Some of these options are personal choice while others are **strongly** recommended (the ones that are more for personal choice are labeled as such). If you continue to support older versions of Python then you at least need to watch out for situations that these solutions fix.

```
from __future__ import print_function
```

This is a personal choice. 2to3 handles the translation from the `print` statement to the `print` function rather well so this is an optional step. This future statement does help, though, with getting used to typing `print('Hello, World')` instead of `print 'Hello, World'`.

```
from __future__ import unicode_literals
```

Another personal choice. You can always mark what you want to be a (unicode) string with a `u` prefix to get the same effect. But regardless of whether you use this future statement or not, you **must** make sure you know exactly which Python 2 strings you want to be bytes, and which are to be strings. This means you should, **at minimum** mark all strings that are meant to be text strings with a `u` prefix if you do not use this future statement.

#### Bytes literals

This is a **very** important one. The ability to prefix Python 2 strings that are meant to contain bytes with a `b` prefix help to very clearly delineate what is and is not a Python 3 string. When you run 2to3 on code, all Python 2 strings become Python 3 strings **unless** they are prefixed with `b`.

There are some differences between byte literals in Python 2 and those in Python 3 thanks to the bytes type just being an alias to `str` in Python 2. Probably the biggest “gotcha” is that indexing results in different values. In Python 2, the value of `b'py'[1]` is `'y'`, while in Python 3 it's `121`. You can avoid this disparity by always slicing at the size of a single element: `b'py'[1:2]` is `'y'` in Python 2 and `b'y'` in Python 3 (i.e., close enough).

You cannot concatenate bytes and strings in Python 3. But since Python 2 has bytes aliased to `str`, it will succeed: `b'a' + u'b'` works in Python 2, but `b'a' + 'b'` in Python 3 is a `TypeError`. A similar issue also comes about when doing comparisons between bytes and strings.

### 3.3 Supporting Python 2.5 and Newer Only

If you are supporting **Python 2.5** and newer there are still some features of Python that you can utilize.

```
from __future__ import absolute_import
```

Implicit relative imports (e.g., importing `spam.bacon` from within `spam.eggs` with the statement `import bacon`) does not work in Python 3. This future statement moves away from that and allows the use of explicit relative imports (e.g., `from . import bacon`).

In Python 2.5 you must use the `__future__` statement to get to use explicit relative imports and prevent implicit ones. In Python 2.6 explicit relative imports are available without the statement, but you still want the `__future__` statement to prevent implicit relative imports. In Python 2.7 the `__future__` statement is not needed. In other words, unless you are only supporting Python 2.7 or a version earlier than Python 2.5, use the `__future__` statement.

### 3.4 Handle Common “Gotchas”

There are a few things that just consistently come up as sticking points for people which 2to3 cannot handle automatically or can easily be done in Python 2 to help modernize your code.

```
from __future__ import division
```

While the exact same outcome can be had by using the `-Qnew` argument to Python, using this future statement lifts the requirement that your users use the flag to get the expected behavior of division in Python 3 (e.g., `1/2 == 0.5`; `1//2 == 0`).

#### Specify when opening a file as binary

Unless you have been working on Windows, there is a chance you have not always bothered to add the `b` mode when opening a binary file (e.g., `rb` for binary reading). Under Python 3, binary files and text files are clearly distinct and mutually incompatible; see the `io` module for details. Therefore, you **must** make a decision of whether a file will be used for binary access (allowing to read and/or write bytes data) or text access (allowing to read and/or write unicode data).

#### Text files

Text files created using `open()` under Python 2 return byte strings, while under Python 3 they return unicode strings. Depending on your porting strategy, this can be an issue.

If you want text files to return unicode strings in Python 2, you have two possibilities:

- Under Python 2.6 and higher, use `io.open()`. Since `io.open()` is essentially the same function in both Python 2 and Python 3, it will help iron out any issues that might arise.
- If pre-2.6 compatibility is needed, then you should use `codecs.open()` instead. This will make sure that you get back unicode strings in Python 2.

#### Subclass object

New-style classes have been around since Python 2.2. You need to make sure you are subclassing from `object` to avoid odd edge cases involving method resolution order, etc. This continues to be totally valid in Python 3 (although unneeded as all classes implicitly inherit from `object`).

## Deal With the Bytes/String Dichotomy

One of the biggest issues people have when porting code to Python 3 is handling the bytes/string dichotomy. Because Python 2 allowed the `str` type to hold textual data, people have over the years been rather loose in their delineation of what `str` instances held text compared to bytes. In Python 3 you cannot be so care-free anymore and need to properly handle the difference. The key handling this issue is to make sure that **every** string literal in your Python 2 code is either syntactically or functionally marked as either bytes or text data. After this is done you then need to make sure your APIs are designed to either handle a specific type or made to be properly polymorphic.

### Mark Up Python 2 String Literals

First thing you must do is designate every single string literal in Python 2 as either textual or bytes data. If you are only supporting Python 2.6 or newer, this can be accomplished by marking bytes literals with a `b` prefix and then designating textual data with a `u` prefix or using the `unicode_literals` future statement.

If your project supports versions of Python predating 2.6, then you should use the `six` project and its `b()` function to denote bytes literals. For text literals you can either use `six`'s `u()` function or use a `u` prefix.

### Decide what APIs Will Accept

In Python 2 it was very easy to accidentally create an API that accepted both bytes and textual data. But in Python 3, thanks to the more strict handling of disparate types, this loose usage of bytes and text together tends to fail.

Take the dict `{b'a': 'bytes', u'a': 'text'}` in Python 2.6. It creates the dict `{u'a': 'text'}` since `b'a' == u'a'`. But in Python 3 the equivalent dict creates `{b'a': 'bytes', 'a': 'text'}`, i.e., no lost data. Similar issues can crop up when transitioning Python 2 code to Python 3.

This means you need to choose what an API is going to accept and create and consistently stick to that API in both Python 2 and 3.

### Bytes / Unicode Comparison

In Python 3, mixing bytes and unicode is forbidden in most situations; it will raise a `TypeError` where Python 2 would have attempted an implicit coercion between types. However, there is one case where it doesn't and it can be very misleading:

```
>>> b"" == ""
False
```

This is because an equality comparison is required by the language to always succeed (and return `False` for incompatible types). However, this also means that code incorrectly ported to Python 3 can display buggy behaviour if such comparisons are silently executed. To detect such situations, Python 3 has a `-b` flag that will display a warning:

```
$ python3 -b
>>> b"" == ""
__main__:1: BytesWarning: Comparison between bytes and string
False
```

To turn the warning into an exception, use the `-bb` flag instead:

```
$ python3 -bb
>>> b"" == ""
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
BytesWarning: Comparison between bytes and string
```

## Indexing bytes objects

Another potentially surprising change is the indexing behaviour of bytes objects in Python 3:

```
>>> b"xyz"[0]
120
```

Indeed, Python 3 bytes objects (as well as `bytearray` objects) are sequences of integers. But code converted from Python 2 will often assume that indexing a bytestring produces another bytestring, not an integer. To reconcile both behaviours, use slicing:

```
>>> b"xyz"[0:1]
b'x'
>>> n = 1
>>> b"xyz"[n:n+1]
b'y'
```

The only remaining gotcha is that an out-of-bounds slice returns an empty bytes object instead of raising `IndexError`:

```
>>> b"xyz"[3]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: index out of range
>>> b"xyz"[3:4]
b''
```

### `__str__()`/`__unicode__()`

In Python 2, objects can specify both a string and unicode representation of themselves. In Python 3, though, there is only a string representation. This becomes an issue as people can inadvertently do things in their `__str__()` methods which have unpredictable results (e.g., infinite recursion if you happen to use the `unicode(self).encode('utf8')` idiom as the body of your `__str__()` method).

There are two ways to solve this issue. One is to use a custom 2to3 fixer. The blog post at <http://lucumr.pocoo.org/2011/1/22/forwards-compatible-python/> specifies how to do this. That will allow 2to3 to change all instances of `def __unicode__(self): ...` to `def __str__(self): ...`. This does require that you define your `__str__()` method in Python 2 before your `__unicode__()` method.

The other option is to use a mixin class. This allows you to only define a `__unicode__()` method for your class and let the mixin derive `__str__()` for you (code from <http://lucumr.pocoo.org/2011/1/22/forwards-compatible-python/>):

```
import sys
```

```
class UnicodeMixin(object):
```

```
    """Mixin class to handle defining the proper __str__/__unicode__
    methods in Python 2 or 3."""
```

```
    if sys.version_info[0] >= 3: # Python 3
        def __str__(self):
            return self.__unicode__()
    else: # Python 2
        def __str__(self):
            return self.__unicode__().encode('utf8')
```

```
class Spam(UnicodeMixin):  
  
    def __unicode__(self):  
        return u'spam-spam-bacon-spam' # 2to3 will remove the 'u' prefix
```

## Don't Index on Exceptions

In Python 2, the following worked:

```
>>> exc = Exception(1, 2, 3)  
>>> exc.args[1]  
2  
>>> exc[1] # Python 2 only!  
2
```

But in Python 3, indexing directly on an exception is an error. You need to make sure to only index on the `BaseException.args` attribute which is a sequence containing all arguments passed to the `__init__()` method.

Even better is to use the documented attributes the exception provides.

## Don't use `__getslice__` & Friends

Been deprecated for a while, but Python 3 finally drops support for `__getslice__()`, etc. Move completely over to `__getitem__()` and friends.

## Updating doctests

`2to3` will attempt to generate fixes for doctests that it comes across. It's not perfect, though. If you wrote a monolithic set of doctests (e.g., a single docstring containing all of your doctests), you should at least consider breaking the doctests up into smaller pieces to make it more manageable to fix. Otherwise it might very well be worth your time and effort to port your tests to `unittest`.

## 3.5 Eliminate `-3` Warnings

When you run your application's test suite, run it using the `-3` flag passed to Python. This will cause various warnings to be raised during execution about things that `2to3` cannot handle automatically (e.g., modules that have been removed). Try to eliminate those warnings to make your code even more portable to Python 3.

## 3.6 Run `2to3`

Once you have made your Python 2 code future-compatible with Python 3, it's time to use `2to3` to actually port your code.

### Manually

To manually convert source code using `2to3`, you use the `2to3` script that is installed with Python 2.6 and later.:

```
2to3 <directory or file to convert>
```

This will cause 2to3 to write out a diff with all of the fixers applied for the converted source code. If you would like 2to3 to go ahead and apply the changes you can pass it the `-w` flag:

```
2to3 -w <stuff to convert>
```

There are other flags available to control exactly which fixers are applied, etc.

## During Installation

When a user installs your project for Python 3, you can have either `distutils` or `Distribute` run 2to3 on your behalf. For `distutils`, use the following idiom:

```
try: # Python 3
    from distutils.command.build_py import build_py_2to3 as build_py
except ImportError: # Python 2
    from distutils.command.build_py import build_py

setup(cmdclass = {'build_py': build_py},
      # ...
    )
```

For `Distribute`:

```
setup(use_2to3=True,
      # ...
    )
```

This will allow you to not have to distribute a separate Python 3 version of your project. It does require, though, that when you perform development that you at least build your project and use the built Python 3 source for testing.

## 3.7 Verify & Test

At this point you should (hopefully) have your project converted in such a way that it works in Python 3. Verify it by running your unit tests and making sure nothing has gone awry. If you miss something then figure out how to fix it in Python 3, backport to your Python 2 code, and run your code through 2to3 again to verify the fix transforms properly.

## 4 Python 2/3 Compatible Source

While it may seem counter-intuitive, you can write Python code which is source-compatible between Python 2 & 3. It does lead to code that is not entirely idiomatic Python (e.g., having to extract the currently raised exception from `sys.exc_info()[1]`), but it can be run under Python 2 **and** Python 3 without using 2to3 as a translation step (although the tool should be used to help find potential portability problems). This allows you to continue to have a rapid development process regardless of whether you are developing under Python 2 or Python 3. Whether this approach or using *Python 2 and 2to3* works best for you will be a per-project decision.

To get a complete idea of what issues you will need to deal with, see the [What's New in Python 3.0](#). Others have reorganized the data in other formats such as [http://docs.pythonsprints.com/python3\\_porting/py-porting.html](http://docs.pythonsprints.com/python3_porting/py-porting.html).

The following are some steps to take to try to support both Python 2 & 3 from the same source code.

### 4.1 Follow The Steps for Using 2to3

All of the steps outlined in how to *port Python 2 code with 2to3* apply to creating a Python 2/3 codebase. This includes trying only support Python 2.6 or newer (the `__future__` statements work in Python 3 without issue), eliminating

warnings that are triggered by `-3`, etc.

You should even consider running `2to3` over your code (without committing the changes). This will let you know where potential pain points are within your code so that you can fix them properly before they become an issue.

## 4.2 Use six

The `six` project contains many things to help you write portable Python code. You should make sure to read its documentation from beginning to end and use any and all features it provides. That way you will minimize any mistakes you might make in writing cross-version code.

## 4.3 Capturing the Currently Raised Exception

One change between Python 2 and 3 that will require changing how you code (if you support Python 2.5 and earlier) is accessing the currently raised exception. In Python 2.5 and earlier the syntax to access the current exception is:

```
try:
    raise Exception()
except Exception, exc:
    # Current exception is 'exc'
    pass
```

This syntax changed in Python 3 (and backported to Python 2.6 and later) to:

```
try:
    raise Exception()
except Exception as exc:
    # Current exception is 'exc'
    # In Python 3, 'exc' is restricted to the block; Python 2.6 will "leak"
    pass
```

Because of this syntax change you must change to capturing the current exception to:

```
try:
    raise Exception()
except Exception:
    import sys
    exc = sys.exc_info()[1]
    # Current exception is 'exc'
    pass
```

You can get more information about the raised exception from `sys.exc_info()` than simply the current exception instance, but you most likely don't need it.

---

**Note:** In Python 3, the traceback is attached to the exception instance through the `__traceback__` attribute. If the instance is saved in a local variable that persists outside of the `except` block, the traceback will create a reference cycle with the current frame and its dictionary of local variables. This will delay reclaiming dead resources until the next cyclic *garbage collection* pass.

In Python 2, this problem only occurs if you save the traceback itself (e.g. the third element of the tuple returned by `sys.exc_info()`) in a variable.

---

## 5 Other Resources

The authors of the following blog posts, wiki pages, and books deserve special thanks for making public their tips for porting Python 2 code to Python 3 (and thus helping provide information for this document):

- <http://python3porting.com/>
- [http://docs.pythonsprints.com/python3\\_porting/py-porting.html](http://docs.pythonsprints.com/python3_porting/py-porting.html)
- <http://techspot.zzzeek.org/2011/01/24/zzzeek-s-guide-to-python-3-porting/>
- <http://dabeaz.blogspot.com/2011/01/porting-py65-and-my-superboard-to.html>
- <http://lucumr.pocoo.org/2011/1/22/forwards-compatible-python/>
- <http://lucumr.pocoo.org/2010/2/11/porting-to-python-3-a-guide/>
- <http://wiki.python.org/moin/PortingPythonToPy3k>

If you feel there is something missing from this document that should be added, please email the [python-porting](mailto:python-porting@python.org) mailing list.

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# Regular Expression HOWTO

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**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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## Abstract

This document is an introductory tutorial to using regular expressions in Python with the `re` module. It provides a gentler introduction than the corresponding section in the Library Reference.

# 1 Introduction

The `re` module was added in Python 1.5, and provides Perl-style regular expression patterns. Earlier versions of Python came with the `regex` module, which provided Emacs-style patterns. The `regex` module was removed completely in Python 2.5.

Regular expressions (called REs, or regexes, or regex patterns) are essentially a tiny, highly specialized programming language embedded inside Python and made available through the `re` module. Using this little language, you specify the rules for the set of possible strings that you want to match; this set might contain English sentences, or e-mail addresses, or TeX commands, or anything you like. You can then ask questions such as “Does this string match the pattern?”, or “Is there a match for the pattern anywhere in this string?”. You can also use REs to modify a string or to split it apart in various ways.

Regular expression patterns are compiled into a series of bytecodes which are then executed by a matching engine written in C. For advanced use, it may be necessary to pay careful attention to how the engine will execute a given RE, and write the RE in a certain way in order to produce bytecode that runs faster. Optimization isn’t covered in this document, because it requires that you have a good understanding of the matching engine’s internals.

The regular expression language is relatively small and restricted, so not all possible string processing tasks can be done using regular expressions. There are also tasks that *can* be done with regular expressions, but the expressions turn out to be very complicated. In these cases, you may be better off writing Python code to do the processing; while Python code will be slower than an elaborate regular expression, it will also probably be more understandable.

## 2 Simple Patterns

We’ll start by learning about the simplest possible regular expressions. Since regular expressions are used to operate on strings, we’ll begin with the most common task: matching characters.

For a detailed explanation of the computer science underlying regular expressions (deterministic and non-deterministic finite automata), you can refer to almost any textbook on writing compilers.

### 2.1 Matching Characters

Most letters and characters will simply match themselves. For example, the regular expression `test` will match the string `test` exactly. (You can enable a case-insensitive mode that would let this RE match `Test` or `TEST` as well; more about this later.)

There are exceptions to this rule; some characters are special *metacharacters*, and don’t match themselves. Instead, they signal that some out-of-the-ordinary thing should be matched, or they affect other portions of the RE by repeating them or changing their meaning. Much of this document is devoted to discussing various metacharacters and what they do.

Here’s a complete list of the metacharacters; their meanings will be discussed in the rest of this HOWTO.

`. ^ $ * + ? { } [ ] \ | ( )`

The first metacharacters we'll look at are `[` and `]`. They're used for specifying a character class, which is a set of characters that you wish to match. Characters can be listed individually, or a range of characters can be indicated by giving two characters and separating them by a `-`. For example, `[abc]` will match any of the characters `a`, `b`, or `c`; this is the same as `[a-c]`, which uses a range to express the same set of characters. If you wanted to match only lowercase letters, your RE would be `[a-z]`.

Metacharacters are not active inside classes. For example, `[akm$]` will match any of the characters `'a'`, `'k'`, `'m'`, or `'$'`; `'$'` is usually a metacharacter, but inside a character class it's stripped of its special nature.

You can match the characters not listed within the class by *complementing* the set. This is indicated by including a `^` as the first character of the class; `^` outside a character class will simply match the `^` character. For example, `[^5]` will match any character except `'5'`.

Perhaps the most important metacharacter is the backslash, `\`. As in Python string literals, the backslash can be followed by various characters to signal various special sequences. It's also used to escape all the metacharacters so you can still match them in patterns; for example, if you need to match a `[` or `\`, you can precede them with a backslash to remove their special meaning: `\[` or `\\`.

Some of the special sequences beginning with `'\'` represent predefined sets of characters that are often useful, such as the set of digits, the set of letters, or the set of anything that isn't whitespace. The following predefined special sequences are a subset of those available. The equivalent classes are for byte string patterns. For a complete list of sequences and expanded class definitions for Unicode string patterns, see the last part of *Regular Expression Syntax*.

`\d` Matches any decimal digit; this is equivalent to the class `[0-9]`.

`\D` Matches any non-digit character; this is equivalent to the class `[^0-9]`.

`\s` Matches any whitespace character; this is equivalent to the class `[\t\n\r\f\v]`.

`\S` Matches any non-whitespace character; this is equivalent to the class `[^\t\n\r\f\v]`.

`\w` Matches any alphanumeric character; this is equivalent to the class `[a-zA-Z0-9_]`.

`\W` Matches any non-alphanumeric character; this is equivalent to the class `[^a-zA-Z0-9_]`.

These sequences can be included inside a character class. For example, `[\s,.]` is a character class that will match any whitespace character, or `'.'` or `','`.

The final metacharacter in this section is `.`. It matches anything except a newline character, and there's an alternate mode (`re.DOTALL`) where it will match even a newline. `'.'` is often used where you want to match "any character".

## 2.2 Repeating Things

Being able to match varying sets of characters is the first thing regular expressions can do that isn't already possible with the methods available on strings. However, if that was the only additional capability of regexes, they wouldn't be much of an advance. Another capability is that you can specify that portions of the RE must be repeated a certain number of times.

The first metacharacter for repeating things that we'll look at is `*`. `*` doesn't match the literal character `*`; instead, it specifies that the previous character can be matched zero or more times, instead of exactly once.

For example, `ca*t` will match `ct` (0 `a` characters), `cat` (1 `a`), `caaat` (3 `a` characters), and so forth. The RE engine has various internal limitations stemming from the size of C's `int` type that will prevent it from matching over 2 billion `a` characters; you probably don't have enough memory to construct a string that large, so you shouldn't run into that limit.

Repetitions such as `*` are *greedy*; when repeating a RE, the matching engine will try to repeat it as many times as possible. If later portions of the pattern don't match, the matching engine will then back up and try again with few repetitions.

A step-by-step example will make this more obvious. Let's consider the expression `a[bcd]*b`. This matches the letter 'a', zero or more letters from the class `[bcd]`, and finally ends with a 'b'. Now imagine matching this RE against the string `abcdb`.

Step	Matched	Explanation
1	a	The a in the RE matches.
2	abcdb	The engine matches <code>[bcd]*</code> , going as far as it can, which is to the end of the string.
3	<i>Failure</i>	The engine tries to match <code>b</code> , but the current position is at the end of the string, so it fails.
4	abcb	Back up, so that <code>[bcd]*</code> matches one less character.
5	<i>Failure</i>	Try <code>b</code> again, but the current position is at the last character, which is a 'd'.
6	abc	Back up again, so that <code>[bcd]*</code> is only matching <code>bc</code> .
6	abcb	Try <code>b</code> again. This time the character at the current position is 'b', so it succeeds.

The end of the RE has now been reached, and it has matched `abcb`. This demonstrates how the matching engine goes as far as it can at first, and if no match is found it will then progressively back up and retry the rest of the RE again and again. It will back up until it has tried zero matches for `[bcd]*`, and if that subsequently fails, the engine will conclude that the string doesn't match the RE at all.

Another repeating metacharacter is `+`, which matches one or more times. Pay careful attention to the difference between `*` and `+`; `*` matches *zero* or more times, so whatever's being repeated may not be present at all, while `+` requires at least *one* occurrence. To use a similar example, `ca+t` will match `cat` (1 a), `caaat` (3 a's), but won't match `ct`.

There are two more repeating qualifiers. The question mark character, `?`, matches either once or zero times; you can think of it as marking something as being optional. For example, `home-?brew` matches either `homebrew` or `home-brew`.

The most complicated repeated qualifier is `{m, n}`, where `m` and `n` are decimal integers. This qualifier means there must be at least `m` repetitions, and at most `n`. For example, `a/{1, 3}b` will match `a/b`, `a//b`, and `a///b`. It won't match `ab`, which has no slashes, or `a////b`, which has four.

You can omit either `m` or `n`; in that case, a reasonable value is assumed for the missing value. Omitting `m` is interpreted as a lower limit of 0, while omitting `n` results in an upper bound of infinity — actually, the upper bound is the 2-billion limit mentioned earlier, but that might as well be infinity.

Readers of a reductionist bent may notice that the three other qualifiers can all be expressed using this notation. `{0, }` is the same as `*`, `{1, }` is equivalent to `+`, and `{0, 1}` is the same as `?`. It's better to use `*`, `+`, or `?` when you can, simply because they're shorter and easier to read.

## 3 Using Regular Expressions

Now that we've looked at some simple regular expressions, how do we actually use them in Python? The `re` module provides an interface to the regular expression engine, allowing you to compile REs into objects and then perform matches with them.

### 3.1 Compiling Regular Expressions

Regular expressions are compiled into pattern objects, which have methods for various operations such as searching for pattern matches or performing string substitutions.

```
>>> import re
>>> p = re.compile('ab*')
>>> p
<_sre.SRE_Pattern object at 0x...>
```

`re.compile()` also accepts an optional *flags* argument, used to enable various special features and syntax variations. We'll go over the available settings later, but for now a single example will do:

```
>>> p = re.compile('ab*', re.IGNORECASE)
```

The RE is passed to `re.compile()` as a string. REs are handled as strings because regular expressions aren't part of the core Python language, and no special syntax was created for expressing them. (There are applications that don't need REs at all, so there's no need to bloat the language specification by including them.) Instead, the `re` module is simply a C extension module included with Python, just like the `socket` or `zlib` modules.

Putting REs in strings keeps the Python language simpler, but has one disadvantage which is the topic of the next section.

## 3.2 The Backslash Plague

As stated earlier, regular expressions use the backslash character (`'\'`) to indicate special forms or to allow special characters to be used without invoking their special meaning. This conflicts with Python's usage of the same character for the same purpose in string literals.

Let's say you want to write a RE that matches the string `\section`, which might be found in a LaTeX file. To figure out what to write in the program code, start with the desired string to be matched. Next, you must escape any backslashes and other metacharacters by preceding them with a backslash, resulting in the string `\\section`. The resulting string that must be passed to `re.compile()` must be `\\\\section`. However, to express this as a Python string literal, both backslashes must be escaped *again*.

Characters	Stage
<code>\section</code>	Text string to be matched
<code>\\section</code>	Escaped backslash for <code>re.compile()</code>
<code>\\\\section</code>	Escaped backslashes for a string literal

In short, to match a literal backslash, one has to write `'\\\\'` as the RE string, because the regular expression must be `\\`, and each backslash must be expressed as `\\` inside a regular Python string literal. In REs that feature backslashes repeatedly, this leads to lots of repeated backslashes and makes the resulting strings difficult to understand.

The solution is to use Python's raw string notation for regular expressions; backslashes are not handled in any special way in a string literal prefixed with `'r'`, so `r"\n"` is a two-character string containing `'\'` and `'n'`, while `"\n"` is a one-character string containing a newline. Regular expressions will often be written in Python code using this raw string notation.

Regular String	Raw string
<code>"ab*"</code>	<code>r"ab*"</code>
<code>\\\\section</code>	<code>r"\\section"</code>
<code>\\w+\\s+\\l</code>	<code>r"\\w+\\s+\\l"</code>

## 3.3 Performing Matches

Once you have an object representing a compiled regular expression, what do you do with it? Pattern objects have several methods and attributes. Only the most significant ones will be covered here; consult the `re` docs for a complete listing.

Method/Attribute	Purpose
<code>match()</code>	Determine if the RE matches at the beginning of the string.
<code>search()</code>	Scan through a string, looking for any location where this RE matches.
<code>findall()</code>	Find all substrings where the RE matches, and returns them as a list.
<code>finditer()</code>	Find all substrings where the RE matches, and returns them as an <i>iterator</i> .

`match()` and `search()` return `None` if no match can be found. If they're successful, a `MatchObject` instance is returned, containing information about the match: where it starts and ends, the substring it matched, and more.

You can learn about this by interactively experimenting with the `re` module. If you have Tkinter available, you may also want to look at [Tools/scripts/redemo.py](#), a demonstration program included with the Python distribution. It allows you to enter REs and strings, and displays whether the RE matches or fails. `redemo.py` can be quite useful when trying to debug a complicated RE. Phil Schwartz's [Kodos](#) is also an interactive tool for developing and testing RE patterns.

This HOWTO uses the standard Python interpreter for its examples. First, run the Python interpreter, import the `re` module, and compile a RE:

```
Python 2.2.2 (#1, Feb 10 2003, 12:57:01)
>>> import re
>>> p = re.compile('[a-z]+')
>>> p #doctest: +ELLIPSIS
<_sre.SRE_Pattern object at 0x...>
```

Now, you can try matching various strings against the RE `[a-z]+`. An empty string shouldn't match at all, since `+` means 'one or more repetitions'. `match()` should return `None` in this case, which will cause the interpreter to print no output. You can explicitly print the result of `match()` to make this clear.

```
>>> p.match("")
>>> print p.match("")
None
```

Now, let's try it on a string that it should match, such as `tempo`. In this case, `match()` will return a `MatchObject`, so you should store the result in a variable for later use.

```
>>> m = p.match('tempo')
>>> m
<_sre.SRE_Match object at 0x...>
```

Now you can query the `MatchObject` for information about the matching string. `MatchObject` instances also have several methods and attributes; the most important ones are:

Method/Attribute	Purpose
<code>group()</code>	Return the string matched by the RE
<code>start()</code>	Return the starting position of the match
<code>end()</code>	Return the ending position of the match
<code>span()</code>	Return a tuple containing the (start, end) positions of the match

Trying these methods will soon clarify their meaning:

```
>>> m.group()
'tempo'
>>> m.start(), m.end()
(0, 5)
>>> m.span()
(0, 5)
```

`group()` returns the substring that was matched by the RE. `start()` and `end()` return the starting and ending index of the match. `span()` returns both start and end indexes in a single tuple. Since the `match()` method only checks if the RE matches at the start of a string, `start()` will always be zero. However, the `search()` method of patterns scans through the string, so the match may not start at zero in that case.

```
>>> print p.match('::: message')
None
>>> m = p.search('::: message'); print m
<_sre.SRE_Match object at 0x...>
```

```
>>> m.group()
'message'
>>> m.span()
(4, 11)
```

In actual programs, the most common style is to store the `MatchObject` in a variable, and then check if it was `None`. This usually looks like:

```
p = re.compile( ... )
m = p.match( 'string goes here' )
if m:
    print 'Match found: ', m.group()
else:
    print 'No match'
```

Two pattern methods return all of the matches for a pattern. `findall()` returns a list of matching strings:

```
>>> p = re.compile('\d+')
>>> p.findall('12 drummers drumming, 11 pipers piping, 10 lords a-leaping')
['12', '11', '10']
```

`findall()` has to create the entire list before it can be returned as the result. The `finditer()` method returns a sequence of `MatchObject` instances as an *iterator*.<sup>1</sup>

```
>>> iterator = p.finditer('12 drummers drumming, 11 ... 10 ...')
>>> iterator
<callable-iterator object at 0x...>
>>> for match in iterator:
...     print match.span()
...
(0, 2)
(22, 24)
(29, 31)
```

## 3.4 Module-Level Functions

You don't have to create a pattern object and call its methods; the `re` module also provides top-level functions called `match()`, `search()`, `findall()`, `sub()`, and so forth. These functions take the same arguments as the corresponding pattern method, with the RE string added as the first argument, and still return either `None` or a `MatchObject` instance.

```
>>> print re.match(r'From\s+', 'Fromage amk')
None
>>> re.match(r'From\s+', 'From amk Thu May 14 19:12:10 1998')
<_sre.SRE_Match object at 0x...>
```

Under the hood, these functions simply create a pattern object for you and call the appropriate method on it. They also store the compiled object in a cache, so future calls using the same RE are faster.

Should you use these module-level functions, or should you get the pattern and call its methods yourself? That choice depends on how frequently the RE will be used, and on your personal coding style. If the RE is being used at only one point in the code, then the module functions are probably more convenient. If a program contains a lot of regular expressions, or re-uses the same ones in several locations, then it might be worthwhile to collect all the definitions in one place, in a section of code that compiles all the REs ahead of time. To take an example from the standard library, here's an extract from the deprecated `xmlilib` module:

---

<sup>1</sup> Introduced in Python 2.2.2.

```

ref = re.compile( ... )
entityref = re.compile( ... )
charref = re.compile( ... )
starttagopen = re.compile( ... )

```

I generally prefer to work with the compiled object, even for one-time uses, but few people will be as much of a purist about this as I am.

### 3.5 Compilation Flags

Compilation flags let you modify some aspects of how regular expressions work. Flags are available in the `re` module under two names, a long name such as `IGNORECASE` and a short, one-letter form such as `I`. (If you're familiar with Perl's pattern modifiers, the one-letter forms use the same letters; the short form of `re.VERBOSE` is `re.X`, for example.) Multiple flags can be specified by bitwise OR-ing them; `re.I | re.M` sets both the `I` and `M` flags, for example.

Here's a table of the available flags, followed by a more detailed explanation of each one.

Flag	Meaning
<code>DOTALL, S</code>	Make <code>.</code> match any character, including newlines
<code>IGNORECASE, I</code>	Do case-insensitive matches
<code>LOCALE, L</code>	Do a locale-aware match
<code>MULTILINE, M</code>	Multi-line matching, affecting <code>^</code> and <code>\$</code>
<code>VERBOSE, X</code>	Enable verbose REs, which can be organized more cleanly and understandably.
<code>UNICODE, U</code>	Makes several escapes like <code>\w</code> , <code>\b</code> , <code>\s</code> and <code>\d</code> dependent on the Unicode character database.

#### I

##### IGNORECASE

Perform case-insensitive matching; character class and literal strings will match letters by ignoring case. For example, `[A-Z]` will match lowercase letters, too, and `Spam` will match `Spam`, `spam`, or `spAM`. This lowercasing doesn't take the current locale into account; it will if you also set the `LOCALE` flag.

#### L

##### LOCALE

Make `\w`, `\W`, `\b`, and `\B`, dependent on the current locale.

Locales are a feature of the C library intended to help in writing programs that take account of language differences. For example, if you're processing French text, you'd want to be able to write `\w+` to match words, but `\w` only matches the character class `[A-Za-z]`; it won't match `'é'` or `'ç'`. If your system is configured properly and a French locale is selected, certain C functions will tell the program that `'é'` should also be considered a letter. Setting the `LOCALE` flag when compiling a regular expression will cause the resulting compiled object to use these C functions for `\w`; this is slower, but also enables `\w+` to match French words as you'd expect.

#### M

##### MULTILINE

(`^` and `$` haven't been explained yet; they'll be introduced in section *More Metacharacters*.)

Usually `^` matches only at the beginning of the string, and `$` matches only at the end of the string and immediately before the newline (if any) at the end of the string. When this flag is specified, `^` matches at the beginning of the string and at the beginning of each line within the string, immediately following each newline. Similarly, the `$` metacharacter matches either at the end of the string and at the end of each line (immediately preceding each newline).

#### S

##### DOTALL

Makes the `'.'` special character match any character at all, including a newline; without this flag, `'.'` will match anything *except* a newline.

## U

### UNICODE

Make `\w`, `\W`, `\b`, `\B`, `\d`, `\D`, `\s` and `\S` dependent on the Unicode character properties database.

## X

### VERBOSE

This flag allows you to write regular expressions that are more readable by granting you more flexibility in how you can format them. When this flag has been specified, whitespace within the RE string is ignored, except when the whitespace is in a character class or preceded by an unescaped backslash; this lets you organize and indent the RE more clearly. This flag also lets you put comments within a RE that will be ignored by the engine; comments are marked by a `' # '` that's neither in a character class or preceded by an unescaped backslash.

For example, here's a RE that uses `re.VERBOSE`; see how much easier it is to read?

```
charref = re.compile(r"""
    &[#]           # Start of a numeric entity reference
    (
        0[0-7]+   # Octal form
        | [0-9]+   # Decimal form
        | x[0-9a-fA-F]+ # Hexadecimal form
    )
    ;             # Trailing semicolon
""", re.VERBOSE)
```

Without the verbose setting, the RE would look like this:

```
charref = re.compile("&#(0[0-7]+"
                    "| [0-9]+"
                    "| x[0-9a-fA-F]+);")
```

In the above example, Python's automatic concatenation of string literals has been used to break up the RE into smaller pieces, but it's still more difficult to understand than the version using `re.VERBOSE`.

## 4 More Pattern Power

So far we've only covered a part of the features of regular expressions. In this section, we'll cover some new metacharacters, and how to use groups to retrieve portions of the text that was matched.

### 4.1 More Metacharacters

There are some metacharacters that we haven't covered yet. Most of them will be covered in this section.

Some of the remaining metacharacters to be discussed are *zero-width assertions*. They don't cause the engine to advance through the string; instead, they consume no characters at all, and simply succeed or fail. For example, `\b` is an assertion that the current position is located at a word boundary; the position isn't changed by the `\b` at all. This means that zero-width assertions should never be repeated, because if they match once at a given location, they can obviously be matched an infinite number of times.

| Alternation, or the "or" operator. If A and B are regular expressions, `A|B` will match any string that matches either A or B. | has very low precedence in order to make it work reasonably when you're alternating multi-character strings. `Crow|Servo` will match either `Crow` or `Servo`, not `Cro`, a `'w'` or an `'S'`, and `ervo`.

To match a literal `'|'`, use `\|`, or enclose it inside a character class, as in `[|]`.

- ^ Matches at the beginning of lines. Unless the MULTILINE flag has been set, this will only match at the beginning of the string. In MULTILINE mode, this also matches immediately after each newline within the string.

For example, if you wish to match the word `From` only at the beginning of a line, the RE to use is `^From`.

```
>>> print re.search('^From', 'From Here to Eternity')
<_sre.SRE_Match object at 0x...>
>>> print re.search('^From', 'Reciting From Memory')
None
```

- \$ Matches at the end of a line, which is defined as either the end of the string, or any location followed by a newline character.

```
>>> print re.search('{}$', '{block}')
<_sre.SRE_Match object at 0x...>
>>> print re.search('{}$', '{block} ')
None
>>> print re.search('{}$', '{block}\n')
<_sre.SRE_Match object at 0x...>
```

To match a literal '\$', use `\$` or enclose it inside a character class, as in `[$]`.

- \A Matches only at the start of the string. When not in MULTILINE mode, `\A` and `^` are effectively the same. In MULTILINE mode, they're different: `\A` still matches only at the beginning of the string, but `^` may match at any location inside the string that follows a newline character.

- \Z Matches only at the end of the string.

- \b Word boundary. This is a zero-width assertion that matches only at the beginning or end of a word. A word is defined as a sequence of alphanumeric characters, so the end of a word is indicated by whitespace or a non-alphanumeric character.

The following example matches `class` only when it's a complete word; it won't match when it's contained inside another word.

```
>>> p = re.compile(r'\bclass\b')
>>> print p.search('no class at all')
<_sre.SRE_Match object at 0x...>
>>> print p.search('the declassified algorithm')
None
>>> print p.search('one subclass is')
None
```

There are two subtleties you should remember when using this special sequence. First, this is the worst collision between Python's string literals and regular expression sequences. In Python's string literals, `\b` is the backspace character, ASCII value 8. If you're not using raw strings, then Python will convert the `\b` to a backspace, and your RE won't match as you expect it to. The following example looks the same as our previous RE, but omits the 'r' in front of the RE string.

```
>>> p = re.compile('\bclass\b')
>>> print p.search('no class at all')
None
>>> print p.search('\b' + 'class' + '\b')
<_sre.SRE_Match object at 0x...>
```

Second, inside a character class, where there's no use for this assertion, `\b` represents the backspace character, for compatibility with Python's string literals.

- \B Another zero-width assertion, this is the opposite of `\b`, only matching when the current position is not at a word boundary.

## 4.2 Grouping

Frequently you need to obtain more information than just whether the RE matched or not. Regular expressions are often used to dissect strings by writing a RE divided into several subgroups which match different components of interest. For example, an RFC-822 header line is divided into a header name and a value, separated by a `:`, like this:

```
From: author@example.com
User-Agent: Thunderbird 1.5.0.9 (X11/20061227)
MIME-Version: 1.0
To: editor@example.com
```

This can be handled by writing a regular expression which matches an entire header line, and has one group which matches the header name, and another group which matches the header's value.

Groups are marked by the `'(, ')` metacharacters. `'(` and `)'` have much the same meaning as they do in mathematical expressions; they group together the expressions contained inside them, and you can repeat the contents of a group with a repeating qualifier, such as `*`, `+`, `?`, or `{m,n}`. For example, `(ab)*` will match zero or more repetitions of `ab`.

```
>>> p = re.compile('(ab)*')
>>> print p.match('ababababab').span()
(0, 10)
```

Groups indicated with `'(, ')` also capture the starting and ending index of the text that they match; this can be retrieved by passing an argument to `group()`, `start()`, `end()`, and `span()`. Groups are numbered starting with 0. Group 0 is always present; it's the whole RE, so `MatchObject` methods all have group 0 as their default argument. Later we'll see how to express groups that don't capture the span of text that they match.

```
>>> p = re.compile('(a)b')
>>> m = p.match('ab')
>>> m.group()
'ab'
>>> m.group(0)
'ab'
```

Subgroups are numbered from left to right, from 1 upward. Groups can be nested; to determine the number, just count the opening parenthesis characters, going from left to right.

```
>>> p = re.compile('(a(b)c)d')
>>> m = p.match('abcd')
>>> m.group(0)
'abcd'
>>> m.group(1)
'abc'
>>> m.group(2)
'b'
```

`group()` can be passed multiple group numbers at a time, in which case it will return a tuple containing the corresponding values for those groups.

```
>>> m.group(2, 1, 2)
('b', 'abc', 'b')
```

The `groups()` method returns a tuple containing the strings for all the subgroups, from 1 up to however many there are.

```
>>> m.groups()
('abc', 'b')
```

Backreferences in a pattern allow you to specify that the contents of an earlier capturing group must also be found at the current location in the string. For example, `\1` will succeed if the exact contents of group 1 can be found at the current position, and fails otherwise. Remember that Python's string literals also use a backslash followed by numbers to allow including arbitrary characters in a string, so be sure to use a raw string when incorporating backreferences in a RE.

For example, the following RE detects doubled words in a string.

```
>>> p = re.compile(r'(\b\w+)\s+\1')
>>> p.search('Paris in the the spring').group()
'the the'
```

Backreferences like this aren't often useful for just searching through a string — there are few text formats which repeat data in this way — but you'll soon find out that they're *very* useful when performing string substitutions.

### 4.3 Non-capturing and Named Groups

Elaborate REs may use many groups, both to capture substrings of interest, and to group and structure the RE itself. In complex REs, it becomes difficult to keep track of the group numbers. There are two features which help with this problem. Both of them use a common syntax for regular expression extensions, so we'll look at that first.

Perl 5 added several additional features to standard regular expressions, and the Python `re` module supports most of them. It would have been difficult to choose new single-keystroke metacharacters or new special sequences beginning with `\` to represent the new features without making Perl's regular expressions confusingly different from standard REs. If you chose `&` as a new metacharacter, for example, old expressions would be assuming that `&` was a regular character and wouldn't have escaped it by writing `\&` or `[&]`.

The solution chosen by the Perl developers was to use `(?..)` as the extension syntax. `?` immediately after a parenthesis was a syntax error because the `?` would have nothing to repeat, so this didn't introduce any compatibility problems. The characters immediately after the `?` indicate what extension is being used, so `(?=foo)` is one thing (a positive lookahead assertion) and `(?:foo)` is something else (a non-capturing group containing the subexpression `foo`).

Python adds an extension syntax to Perl's extension syntax. If the first character after the question mark is a `P`, you know that it's an extension that's specific to Python. Currently there are two such extensions: `(?P<name>..)` defines a named group, and `(?P=name)` is a backreference to a named group. If future versions of Perl 5 add similar features using a different syntax, the `re` module will be changed to support the new syntax, while preserving the Python-specific syntax for compatibility's sake.

Now that we've looked at the general extension syntax, we can return to the features that simplify working with groups in complex REs. Since groups are numbered from left to right and a complex expression may use many groups, it can become difficult to keep track of the correct numbering. Modifying such a complex RE is annoying, too: insert a new group near the beginning and you change the numbers of everything that follows it.

Sometimes you'll want to use a group to collect a part of a regular expression, but aren't interested in retrieving the group's contents. You can make this fact explicit by using a non-capturing group: `(?:..)`, where you can replace the `..` with any other regular expression.

```
>>> m = re.match("([abc])+", "abc")
>>> m.groups()
('c',)
>>> m = re.match("(?:[abc])+", "abc")
>>> m.groups()
()
```

Except for the fact that you can't retrieve the contents of what the group matched, a non-capturing group behaves exactly the same as a capturing group; you can put anything inside it, repeat it with a repetition metacharacter such as `*`, and nest it within other groups (capturing or non-capturing). `(?:..)` is particularly useful when modifying an



Notice that the `.` needs to be treated specially because it's a metacharacter; I've put it inside a character class. Also notice the trailing `$`; this is added to ensure that all the rest of the string must be included in the extension. This regular expression matches `foo.bar` and `autoexec.bat` and `sendmail.cf` and `printers.conf`.

Now, consider complicating the problem a bit; what if you want to match filenames where the extension is not `bat`? Some incorrect attempts:

`.*[.]^[^b].*$` The first attempt above tries to exclude `bat` by requiring that the first character of the extension is not a `b`. This is wrong, because the pattern also doesn't match `foo.bar`.

`.*[.]([^\b]...|^[^a]...|^[^t])$`

The expression gets messier when you try to patch up the first solution by requiring one of the following cases to match: the first character of the extension isn't `b`; the second character isn't `a`; or the third character isn't `t`. This accepts `foo.bar` and rejects `autoexec.bat`, but it requires a three-letter extension and won't accept a filename with a two-letter extension such as `sendmail.cf`. We'll complicate the pattern again in an effort to fix it.

`.*[.]([^\b].??.?|^[^a]??.?|...?^[^t]?)$`

In the third attempt, the second and third letters are all made optional in order to allow matching extensions shorter than three characters, such as `sendmail.cf`.

The pattern's getting really complicated now, which makes it hard to read and understand. Worse, if the problem changes and you want to exclude both `bat` and `exe` as extensions, the pattern would get even more complicated and confusing.

A negative lookahead cuts through all this confusion:

`.*[.](!bat$).*$` The negative lookahead means: if the expression `bat` doesn't match at this point, try the rest of the pattern; if `bat$` does match, the whole pattern will fail. The trailing `$` is required to ensure that something like `sample.batch`, where the extension only starts with `bat`, will be allowed.

Excluding another filename extension is now easy; simply add it as an alternative inside the assertion. The following pattern excludes filenames that end in either `bat` or `exe`:

`.*[.](!bat$|exe$).*$`

## 5 Modifying Strings

Up to this point, we've simply performed searches against a static string. Regular expressions are also commonly used to modify strings in various ways, using the following pattern methods:

Method/Attribute	Purpose
<code>split()</code>	Split the string into a list, splitting it wherever the RE matches
<code>sub()</code>	Find all substrings where the RE matches, and replace them with a different string
<code>subn()</code>	Does the same thing as <code>sub()</code> , but returns the new string and the number of replacements

### 5.1 Splitting Strings

The `split()` method of a pattern splits a string apart wherever the RE matches, returning a list of the pieces. It's similar to the `split()` method of strings but provides much more generality in the delimiters that you can split by; `split()` only supports splitting by whitespace or by a fixed string. As you'd expect, there's a module-level `re.split()` function, too.

`.split(string[, maxsplit=0])`

Split `string` by the matches of the regular expression. If capturing parentheses are used in the RE, then their contents will also be returned as part of the resulting list. If `maxsplit` is nonzero, at most `maxsplit` splits are performed.

You can limit the number of splits made, by passing a value for *maxsplit*. When *maxsplit* is nonzero, at most *maxsplit* splits will be made, and the remainder of the string is returned as the final element of the list. In the following example, the delimiter is any sequence of non-alphanumeric characters.

```
>>> p = re.compile(r'\W+')
>>> p.split('This is a test, short and sweet, of split().')
['This', 'is', 'a', 'test', 'short', 'and', 'sweet', 'of', 'split', '']
>>> p.split('This is a test, short and sweet, of split().', 3)
['This', 'is', 'a', 'test, short and sweet, of split().']
```

Sometimes you're not only interested in what the text between delimiters is, but also need to know what the delimiter was. If capturing parentheses are used in the RE, then their values are also returned as part of the list. Compare the following calls:

```
>>> p = re.compile(r'\W+')
>>> p2 = re.compile(r'(\W+)')
>>> p.split('This... is a test.')
['This', 'is', 'a', 'test', '']
>>> p2.split('This... is a test.')
['This', '...', 'is', ' ', 'a', ' ', 'test', '.', '']
```

The module-level function `re.split()` adds the RE to be used as the first argument, but is otherwise the same.

```
>>> re.split('[\W]+', 'Words, words, words.')
['Words', 'words', 'words', '']
>>> re.split('([\W]+)', 'Words, words, words.')
['Words', ' ', ' ', 'words', ' ', ' ', 'words', '.', '']
>>> re.split('[\W]+', 'Words, words, words.', 1)
['Words', 'words, words.']
```

## 5.2 Search and Replace

Another common task is to find all the matches for a pattern, and replace them with a different string. The `sub()` method takes a replacement value, which can be either a string or a function, and the string to be processed.

**.sub** (*replacement*, *string* [, *count=0* ])

Returns the string obtained by replacing the leftmost non-overlapping occurrences of the RE in *string* by the replacement *replacement*. If the pattern isn't found, *string* is returned unchanged.

The optional argument *count* is the maximum number of pattern occurrences to be replaced; *count* must be a non-negative integer. The default value of 0 means to replace all occurrences.

Here's a simple example of using the `sub()` method. It replaces colour names with the word `colour`:

```
>>> p = re.compile(' (blue|white|red) ')
>>> p.sub('colour', 'blue socks and red shoes')
'colour socks and colour shoes'
>>> p.sub('colour', 'blue socks and red shoes', count=1)
'colour socks and red shoes'
```

The `subn()` method does the same work, but returns a 2-tuple containing the new string value and the number of replacements that were performed:

```
>>> p = re.compile(' (blue|white|red) ')
>>> p.subn('colour', 'blue socks and red shoes')
('colour socks and colour shoes', 2)
>>> p.subn('colour', 'no colours at all')
('no colours at all', 0)
```

Empty matches are replaced only when they're not adjacent to a previous match.

```
>>> p = re.compile('x*')
>>> p.sub('-', 'abxd')
'-a-b-d-'
```

If *replacement* is a string, any backslash escapes in it are processed. That is, `\n` is converted to a single newline character, `\r` is converted to a carriage return, and so forth. Unknown escapes such as `\j` are left alone. Backreferences, such as `\6`, are replaced with the substring matched by the corresponding group in the RE. This lets you incorporate portions of the original text in the resulting replacement string.

This example matches the word `section` followed by a string enclosed in `{, }`, and changes `section` to `subsection`:

```
>>> p = re.compile('section{ ( [^}]* ) }', re.VERBOSE)
>>> p.sub(r'subsection{\1}', 'section{First} section{second}')
'subsection{First} subsection{second}'
```

There's also a syntax for referring to named groups as defined by the `(?P<name>...)` syntax. `\g<name>` will use the substring matched by the group named `name`, and `\g<number>` uses the corresponding group number. `\g<2>` is therefore equivalent to `\2`, but isn't ambiguous in a replacement string such as `\g<2>0`. (`\20` would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character `'0'`.) The following substitutions are all equivalent, but use all three variations of the replacement string.

```
>>> p = re.compile('section{ (?P<name> [^}]* ) }', re.VERBOSE)
>>> p.sub(r'subsection{\1}', 'section{First}')
'subsection{First}'
>>> p.sub(r'subsection{\g<1>}', 'section{First}')
'subsection{First}'
>>> p.sub(r'subsection{\g<name>}', 'section{First}')
'subsection{First}'
```

*replacement* can also be a function, which gives you even more control. If *replacement* is a function, the function is called for every non-overlapping occurrence of *pattern*. On each call, the function is passed a `MatchObject` argument for the match and can use this information to compute the desired replacement string and return it.

In the following example, the replacement function translates decimals into hexadecimal:

```
>>> def hexrepl(match):
...     "Return the hex string for a decimal number"
...     value = int(match.group())
...     return hex(value)
...
>>> p = re.compile(r'\d+')
>>> p.sub(hexrepl, 'Call 65490 for printing, 49152 for user code.')
'Call 0xffd2 for printing, 0xc000 for user code.'
```

When using the module-level `re.sub()` function, the pattern is passed as the first argument. The pattern may be provided as an object or as a string; if you need to specify regular expression flags, you must either use a pattern object as the first parameter, or use embedded modifiers in the pattern string, e.g. `sub("(?i)b+", "x", "bbbb BBBB")` returns `'x x'`.

## 6 Common Problems

Regular expressions are a powerful tool for some applications, but in some ways their behaviour isn't intuitive and at times they don't behave the way you may expect them to. This section will point out some of the most common pitfalls.

## 6.1 Use String Methods

Sometimes using the `re` module is a mistake. If you're matching a fixed string, or a single character class, and you're not using any `re` features such as the `IGNORECASE` flag, then the full power of regular expressions may not be required. Strings have several methods for performing operations with fixed strings and they're usually much faster, because the implementation is a single small C loop that's been optimized for the purpose, instead of the large, more generalized regular expression engine.

One example might be replacing a single fixed string with another one; for example, you might replace `word` with `deed`. `re.sub()` seems like the function to use for this, but consider the `replace()` method. Note that `replace()` will also replace `word` inside words, turning `swordfish` into `sdeedfish`, but the naive RE `word` would have done that, too. (To avoid performing the substitution on parts of words, the pattern would have to be `\bword\b`, in order to require that `word` have a word boundary on either side. This takes the job beyond `replace()`'s abilities.)

Another common task is deleting every occurrence of a single character from a string or replacing it with another single character. You might do this with something like `re.sub('\n', ' ', S)`, but `translate()` is capable of doing both tasks and will be faster than any regular expression operation can be.

In short, before turning to the `re` module, consider whether your problem can be solved with a faster and simpler string method.

## 6.2 `match()` versus `search()`

The `match()` function only checks if the RE matches at the beginning of the string while `search()` will scan forward through the string for a match. It's important to keep this distinction in mind. Remember, `match()` will only report a successful match which will start at 0; if the match wouldn't start at zero, `match()` will *not* report it.

```
>>> print re.match('super', 'superstition').span()
(0, 5)
>>> print re.match('super', 'insuperable')
None
```

On the other hand, `search()` will scan forward through the string, reporting the first match it finds.

```
>>> print re.search('super', 'superstition').span()
(0, 5)
>>> print re.search('super', 'insuperable').span()
(2, 7)
```

Sometimes you'll be tempted to keep using `re.match()`, and just add `.*` to the front of your RE. Resist this temptation and use `re.search()` instead. The regular expression compiler does some analysis of REs in order to speed up the process of looking for a match. One such analysis figures out what the first character of a match must be; for example, a pattern starting with `Crow` must match starting with a `'C'`. The analysis lets the engine quickly scan through the string looking for the starting character, only trying the full match if a `'C'` is found.

Adding `.*` defeats this optimization, requiring scanning to the end of the string and then backtracking to find a match for the rest of the RE. Use `re.search()` instead.

## 6.3 Greedy versus Non-Greedy

When repeating a regular expression, as in `a*`, the resulting action is to consume as much of the pattern as possible. This fact often bites you when you're trying to match a pair of balanced delimiters, such as the angle brackets surrounding an HTML tag. The naive pattern for matching a single HTML tag doesn't work because of the greedy nature of `.*`.

```

>>> s = '<html><head><title>Title</title>'
>>> len(s)
32
>>> print re.match('<.*>', s).span()
(0, 32)
>>> print re.match('<.*>', s).group()
<html><head><title>Title</title>

```

The RE matches the '`<`' in `<html>`, and the `.*` consumes the rest of the string. There's still more left in the RE, though, and the `>` can't match at the end of the string, so the regular expression engine has to backtrack character by character until it finds a match for the `>`. The final match extends from the '`<`' in `<html>` to the '`>`' in `</title>`, which isn't what you want.

In this case, the solution is to use the non-greedy qualifiers `*?`, `+?`, `??`, or `{m,n}?`, which match as *little* text as possible. In the above example, the '`>`' is tried immediately after the first '`<`' matches, and when it fails, the engine advances a character at a time, retrying the '`>`' at every step. This produces just the right result:

```

>>> print re.match('<.*?>', s).group()
<html>

```

(Note that parsing HTML or XML with regular expressions is painful. Quick-and-dirty patterns will handle common cases, but HTML and XML have special cases that will break the obvious regular expression; by the time you've written a regular expression that handles all of the possible cases, the patterns will be *very* complicated. Use an HTML or XML parser module for such tasks.)

## 6.4 Using re.VERBOSE

By now you've probably noticed that regular expressions are a very compact notation, but they're not terribly readable. REs of moderate complexity can become lengthy collections of backslashes, parentheses, and metacharacters, making them difficult to read and understand.

For such REs, specifying the `re.VERBOSE` flag when compiling the regular expression can be helpful, because it allows you to format the regular expression more clearly.

The `re.VERBOSE` flag has several effects. Whitespace in the regular expression that *isn't* inside a character class is ignored. This means that an expression such as `dog | cat` is equivalent to the less readable `dog|cat`, but `[a b]` will still match the characters '`a`', '`b`', or a space. In addition, you can also put comments inside a RE; comments extend from a `#` character to the next newline. When used with triple-quoted strings, this enables REs to be formatted more neatly:

```

pat = re.compile(r"""
\s*           # Skip leading whitespace
(?:P<header>[^:]+) # Header name
\s* :        # Whitespace, and a colon
(?:P<value>.*?) # The header's value -- *? used to
               # lose the following trailing whitespace
\s*$        # Trailing whitespace to end-of-line
""", re.VERBOSE)

```

This is far more readable than:

```

pat = re.compile(r"\s*(?:P<header>[^:]+)\s*:(?:P<value>.*?)\s*$")

```

## 7 Feedback

Regular expressions are a complicated topic. Did this document help you understand them? Were there parts that were unclear, or Problems you encountered that weren't covered here? If so, please send suggestions for improvements to the author.

The most complete book on regular expressions is almost certainly Jeffrey Friedl's *Mastering Regular Expressions*, published by O'Reilly. Unfortunately, it exclusively concentrates on Perl and Java's flavours of regular expressions, and doesn't contain any Python material at all, so it won't be useful as a reference for programming in Python. (The first edition covered Python's now-removed `regex` module, which won't help you much.) Consider checking it out from your library.

---

# Socket Programming HOWTO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

September 24, 2012

**Python Software Foundation**  
Email: docs@python.org

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**Author** Gordon McMillan

### Abstract

Sockets are used nearly everywhere, but are one of the most severely misunderstood technologies around. This is a 10,000 foot overview of sockets. It's not really a tutorial - you'll still have work to do in getting things operational. It doesn't cover the fine points (and there are a lot of them), but I hope it will give you enough background to begin using them decently.

# 1 Sockets

Sockets are used nearly everywhere, but are one of the most severely misunderstood technologies around. This is a 10,000 foot overview of sockets. It's not really a tutorial - you'll still have work to do in getting things working. It doesn't cover the fine points (and there are a lot of them), but I hope it will give you enough background to begin using them decently.

I'm only going to talk about INET sockets, but they account for at least 99% of the sockets in use. And I'll only talk about STREAM sockets - unless you really know what you're doing (in which case this HOWTO isn't for you!), you'll get better behavior and performance from a STREAM socket than anything else. I will try to clear up the mystery of what a socket is, as well as some hints on how to work with blocking and non-blocking sockets. But I'll start by talking about blocking sockets. You'll need to know how they work before dealing with non-blocking sockets.

Part of the trouble with understanding these things is that "socket" can mean a number of subtly different things, depending on context. So first, let's make a distinction between a "client" socket - an endpoint of a conversation, and a "server" socket, which is more like a switchboard operator. The client application (your browser, for example) uses "client" sockets exclusively; the web server it's talking to uses both "server" sockets and "client" sockets.

## 1.1 History

Of the various forms of IPC (Inter Process Communication), sockets are by far the most popular. On any given platform, there are likely to be other forms of IPC that are faster, but for cross-platform communication, sockets are about the only game in town.

They were invented in Berkeley as part of the BSD flavor of Unix. They spread like wildfire with the Internet. With good reason — the combination of sockets with INET makes talking to arbitrary machines around the world unbelievably easy (at least compared to other schemes).

## 2 Creating a Socket

Roughly speaking, when you clicked on the link that brought you to this page, your browser did something like the following:

```
#create an INET, STREAMing socket
s = socket.socket(
    socket.AF_INET, socket.SOCK_STREAM)
#now connect to the web server on port 80
# - the normal http port
s.connect(("www.mcmillan-inc.com", 80))
```

When the `connect` completes, the socket `s` can be used to send in a request for the text of the page. The same socket will read the reply, and then be destroyed. That's right, destroyed. Client sockets are normally only used for one exchange (or a small set of sequential exchanges).

What happens in the web server is a bit more complex. First, the web server creates a "server socket":

```
#create an INET, STREAMing socket
serversocket = socket.socket(
    socket.AF_INET, socket.SOCK_STREAM)
#bind the socket to a public host,
# and a well-known port
serversocket.bind((socket.gethostname(), 80))
#become a server socket
serversocket.listen(5)
```

A couple things to notice: we used `socket.gethostname()` so that the socket would be visible to the outside world. If we had used `s.bind(("", 80))` or `s.bind('localhost', 80))` or `s.bind('127.0.0.1', 80))` we would still have a “server” socket, but one that was only visible within the same machine.

A second thing to note: low number ports are usually reserved for “well known” services (HTTP, SNMP etc). If you’re playing around, use a nice high number (4 digits).

Finally, the argument to `listen` tells the socket library that we want it to queue up as many as 5 connect requests (the normal max) before refusing outside connections. If the rest of the code is written properly, that should be plenty.

Now that we have a “server” socket, listening on port 80, we can enter the mainloop of the web server:

```
while 1:
    #accept connections from outside
    (clientsocket, address) = serversocket.accept()
    #now do something with the clientsocket
    #in this case, we'll pretend this is a threaded server
    ct = client_thread(clientsocket)
    ct.run()
```

There’s actually 3 general ways in which this loop could work - dispatching a thread to handle `clientsocket`, create a new process to handle `clientsocket`, or restructure this app to use non-blocking sockets, and multiplex between our “server” socket and any active `clientsockets` using `select`. More about that later. The important thing to understand now is this: this is *all* a “server” socket does. It doesn’t send any data. It doesn’t receive any data. It just produces “client” sockets. Each `clientsocket` is created in response to some *other* “client” socket doing a `connect()` to the host and port we’re bound to. As soon as we’ve created that `clientsocket`, we go back to listening for more connections. The two “clients” are free to chat it up - they are using some dynamically allocated port which will be recycled when the conversation ends.

## 2.1 IPC

If you need fast IPC between two processes on one machine, you should look into whatever form of shared memory the platform offers. A simple protocol based around shared memory and locks or semaphores is by far the fastest technique.

If you do decide to use sockets, bind the “server” socket to `'localhost'`. On most platforms, this will take a shortcut around a couple of layers of network code and be quite a bit faster.

## 3 Using a Socket

The first thing to note, is that the web browser’s “client” socket and the web server’s “client” socket are identical beasts. That is, this is a “peer to peer” conversation. Or to put it another way, *as the designer, you will have to decide what the rules of etiquette are for a conversation*. Normally, the connecting socket starts the conversation, by sending in a request, or perhaps a signon. But that’s a design decision - it’s not a rule of sockets.

Now there are two sets of verbs to use for communication. You can use `send` and `recv`, or you can transform your client socket into a file-like beast and use `read` and `write`. The latter is the way Java presents its sockets. I’m not going to talk about it here, except to warn you that you need to use `flush` on sockets. These are buffered “files”, and a common mistake is to `write` something, and then `read` for a reply. Without a `flush` in there, you may wait forever for the reply, because the request may still be in your output buffer.

Now we come to the major stumbling block of sockets - `send` and `recv` operate on the network buffers. They do not necessarily handle all the bytes you hand them (or expect from them), because their major focus is handling the network buffers. In general, they return when the associated network buffers have been filled (`send`) or emptied

(recv). They then tell you how many bytes they handled. It is *your* responsibility to call them again until your message has been completely dealt with.

When a `recv` returns 0 bytes, it means the other side has closed (or is in the process of closing) the connection. You will not receive any more data on this connection. Ever. You may be able to send data successfully; I'll talk more about this later.

A protocol like HTTP uses a socket for only one transfer. The client sends a request, then reads a reply. That's it. The socket is discarded. This means that a client can detect the end of the reply by receiving 0 bytes.

But if you plan to reuse your socket for further transfers, you need to realize that *there is no* EOT (End of Transfer) *on a socket*. I repeat: if a socket `send` or `recv` returns after handling 0 bytes, the connection has been broken. If the connection has *not* been broken, you may wait on a `recv` forever, because the socket will *not* tell you that there's nothing more to read (for now). Now if you think about that a bit, you'll come to realize a fundamental truth of sockets: *messages must either be fixed length* (yuck), *or be delimited* (shrug), *or indicate how long they are* (much better), *or end by shutting down the connection*. The choice is entirely yours, (but some ways are righter than others).

Assuming you don't want to end the connection, the simplest solution is a fixed length message:

```
class mysocket:
    '''demonstration class only
    - coded for clarity, not efficiency
    '''

    def __init__(self, sock=None):
        if sock is None:
            self.sock = socket.socket(
                socket.AF_INET, socket.SOCK_STREAM)
        else:
            self.sock = sock

    def connect(self, host, port):
        self.sock.connect((host, port))

    def mysend(self, msg):
        totalsent = 0
        while totalsent < MSGLEN:
            sent = self.sock.send(msg[totalsent:])
            if sent == 0:
                raise RuntimeError("socket connection broken")
            totalsent = totalsent + sent

    def myreceive(self):
        msg = ''
        while len(msg) < MSGLEN:
            chunk = self.sock.recv(MSGLEN-len(msg))
            if chunk == '':
                raise RuntimeError("socket connection broken")
            msg = msg + chunk
        return msg
```

The sending code here is usable for almost any messaging scheme - in Python you send strings, and you can use `len()` to determine its length (even if it has embedded `\0` characters). It's mostly the receiving code that gets more complex. (And in C, it's not much worse, except you can't use `strlen` if the message has embedded `\0`s.)

The easiest enhancement is to make the first character of the message an indicator of message type, and have the type determine the length. Now you have two `recvs` - the first to get (at least) that first character so you can look up the

length, and the second in a loop to get the rest. If you decide to go the delimited route, you'll be receiving in some arbitrary chunk size, (4096 or 8192 is frequently a good match for network buffer sizes), and scanning what you've received for a delimiter.

One complication to be aware of: if your conversational protocol allows multiple messages to be sent back to back (without some kind of reply), and you pass `recv` an arbitrary chunk size, you may end up reading the start of a following message. You'll need to put that aside and hold onto it, until it's needed.

Prefixing the message with its length (say, as 5 numeric characters) gets more complex, because (believe it or not), you may not get all 5 characters in one `recv`. In playing around, you'll get away with it; but in high network loads, your code will very quickly break unless you use two `recv` loops - the first to determine the length, the second to get the data part of the message. Nasty. This is also when you'll discover that `send` does not always manage to get rid of everything in one pass. And despite having read this, you will eventually get bit by it!

In the interests of space, building your character, (and preserving my competitive position), these enhancements are left as an exercise for the reader. Lets move on to cleaning up.

### 3.1 Binary Data

It is perfectly possible to send binary data over a socket. The major problem is that not all machines use the same formats for binary data. For example, a Motorola chip will represent a 16 bit integer with the value 1 as the two hex bytes 00 01. Intel and DEC, however, are byte-reversed - that same 1 is 01 00. Socket libraries have calls for converting 16 and 32 bit integers - `ntohl`, `htonl`, `ntohs`, `htons` where "n" means *network* and "h" means *host*, "s" means *short* and "l" means *long*. Where network order is host order, these do nothing, but where the machine is byte-reversed, these swap the bytes around appropriately.

In these days of 32 bit machines, the ascii representation of binary data is frequently smaller than the binary representation. That's because a surprising amount of the time, all those longs have the value 0, or maybe 1. The string "0" would be two bytes, while binary is four. Of course, this doesn't fit well with fixed-length messages. Decisions, decisions.

## 4 Disconnecting

Strictly speaking, you're supposed to use `shutdown` on a socket before you `close` it. The `shutdown` is an advisory to the socket at the other end. Depending on the argument you pass it, it can mean "I'm not going to send anymore, but I'll still listen", or "I'm not listening, good riddance!". Most socket libraries, however, are so used to programmers neglecting to use this piece of etiquette that normally a `close` is the same as `shutdown(); close()`. So in most situations, an explicit `shutdown` is not needed.

One way to use `shutdown` effectively is in an HTTP-like exchange. The client sends a request and then does a `shutdown(1)`. This tells the server "This client is done sending, but can still receive." The server can detect "EOF" by a receive of 0 bytes. It can assume it has the complete request. The server sends a reply. If the `send` completes successfully then, indeed, the client was still receiving.

Python takes the automatic shutdown a step further, and says that when a socket is garbage collected, it will automatically do a `close` if it's needed. But relying on this is a very bad habit. If your socket just disappears without doing a `close`, the socket at the other end may hang indefinitely, thinking you're just being slow. *Please close* your sockets when you're done.

### 4.1 When Sockets Die

Probably the worst thing about using blocking sockets is what happens when the other side comes down hard (without doing a `close`). Your socket is likely to hang. SOCKSTREAM is a reliable protocol, and it will wait a long, long time before giving up on a connection. If you're using threads, the entire thread is essentially dead. There's not much

you can do about it. As long as you aren't doing something dumb, like holding a lock while doing a blocking read, the thread isn't really consuming much in the way of resources. Do *not* try to kill the thread - part of the reason that threads are more efficient than processes is that they avoid the overhead associated with the automatic recycling of resources. In other words, if you do manage to kill the thread, your whole process is likely to be screwed up.

## 5 Non-blocking Sockets

If you've understood the preceding, you already know most of what you need to know about the mechanics of using sockets. You'll still use the same calls, in much the same ways. It's just that, if you do it right, your app will be almost inside-out.

In Python, you use `socket.setblocking(0)` to make it non-blocking. In C, it's more complex, (for one thing, you'll need to choose between the BSD flavor `O_NONBLOCK` and the almost indistinguishable Posix flavor `O_NDELAY`, which is completely different from `TCP_NODELAY`), but it's the exact same idea. You do this after creating the socket, but before using it. (Actually, if you're nuts, you can switch back and forth.)

The major mechanical difference is that `send`, `recv`, `connect` and `accept` can return without having done anything. You have (of course) a number of choices. You can check return code and error codes and generally drive yourself crazy. If you don't believe me, try it sometime. Your app will grow large, buggy and suck CPU. So let's skip the brain-dead solutions and do it right.

Use `select`.

In C, coding `select` is fairly complex. In Python, it's a piece of cake, but it's close enough to the C version that if you understand `select` in Python, you'll have little trouble with it in C:

```
ready_to_read, ready_to_write, in_error = \
    select.select(
        potential_readers,
        potential_writers,
        potential_errs,
        timeout)
```

You pass `select` three lists: the first contains all sockets that you might want to try reading; the second all the sockets you might want to try writing to, and the last (normally left empty) those that you want to check for errors. You should note that a socket can go into more than one list. The `select` call is blocking, but you can give it a timeout. This is generally a sensible thing to do - give it a nice long timeout (say a minute) unless you have good reason to do otherwise.

In return, you will get three lists. They contain the sockets that are actually readable, writable and in error. Each of these lists is a subset (possibly empty) of the corresponding list you passed in.

If a socket is in the output readable list, you can be as-close-to-certain-as-we-ever-get-in-this-business that a `recv` on that socket will return *something*. Same idea for the writable list. You'll be able to send *something*. Maybe not all you want to, but *something* is better than nothing. (Actually, any reasonably healthy socket will return as writable - it just means outbound network buffer space is available.)

If you have a "server" socket, put it in the `potential_readers` list. If it comes out in the readable list, your `accept` will (almost certainly) work. If you have created a new socket to `connect` to someone else, put it in the `potential_writers` list. If it shows up in the writable list, you have a decent chance that it has connected.

One very nasty problem with `select`: if somewhere in those input lists of sockets is one which has died a nasty death, the `select` will fail. You then need to loop through every single damn socket in all those lists and do a `select([sock], [], [], 0)` until you find the bad one. That timeout of 0 means it won't take long, but it's ugly.

Actually, `select` can be handy even with blocking sockets. It's one way of determining whether you will block - the socket returns as readable when there's something in the buffers. However, this still doesn't help with the problem of determining whether the other end is done, or just busy with something else.

**Portability alert:** On Unix, `select` works both with the sockets and files. Don't try this on Windows. On Windows, `select` works with sockets only. Also note that in C, many of the more advanced socket options are done differently on Windows. In fact, on Windows I usually use threads (which work very, very well) with my sockets. Face it, if you want any kind of performance, your code will look very different on Windows than on Unix.

## 5.1 Performance

There's no question that the fastest sockets code uses non-blocking sockets and `select` to multiplex them. You can put together something that will saturate a LAN connection without putting any strain on the CPU. The trouble is that an app written this way can't do much of anything else - it needs to be ready to shuffle bytes around at all times.

Assuming that your app is actually supposed to do something more than that, threading is the optimal solution, (and using non-blocking sockets will be faster than using blocking sockets). Unfortunately, threading support in Unixes varies both in API and quality. So the normal Unix solution is to fork a subprocess to deal with each connection. The overhead for this is significant (and don't do this on Windows - the overhead of process creation is enormous there). It also means that unless each subprocess is completely independent, you'll need to use another form of IPC, say a pipe, or shared memory and semaphores, to communicate between the parent and child processes.

Finally, remember that even though blocking sockets are somewhat slower than non-blocking, in many cases they are the "right" solution. After all, if your app is driven by the data it receives over a socket, there's not much sense in complicating the logic just so your app can wait on `select` instead of `recv`.

---

# Sorting HOW TO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Andrew Dalke and Raymond Hettinger

**Release** 0.1

Python lists have a built-in `list.sort()` method that modifies the list in-place. There is also a `sorted()` built-in function that builds a new sorted list from an iterable.

In this document, we explore the various techniques for sorting data using Python.

## 1 Sorting Basics

A simple ascending sort is very easy: just call the `sorted()` function. It returns a new sorted list:

```
>>> sorted([5, 2, 3, 1, 4])
[1, 2, 3, 4, 5]
```

You can also use the `list.sort()` method of a list. It modifies the list in-place (and returns *None* to avoid confusion). Usually it's less convenient than `sorted()` - but if you don't need the original list, it's slightly more efficient.

```
>>> a = [5, 2, 3, 1, 4]
>>> a.sort()
>>> a
[1, 2, 3, 4, 5]
```

Another difference is that the `list.sort()` method is only defined for lists. In contrast, the `sorted()` function accepts any iterable.

```
>>> sorted({1: 'D', 2: 'B', 3: 'B', 4: 'E', 5: 'A'})
[1, 2, 3, 4, 5]
```

## 2 Key Functions

Starting with Python 2.4, both `list.sort()` and `sorted()` added a *key* parameter to specify a function to be called on each list element prior to making comparisons.

For example, here's a case-insensitive string comparison:

```
>>> sorted("This is a test string from Andrew".split(), key=str.lower)
['a', 'Andrew', 'from', 'is', 'string', 'test', 'This']
```

The value of the *key* parameter should be a function that takes a single argument and returns a key to use for sorting purposes. This technique is fast because the key function is called exactly once for each input record.

A common pattern is to sort complex objects using some of the object's indices as keys. For example:

```
>>> student_tuples = [
    ('john', 'A', 15),
    ('jane', 'B', 12),
    ('dave', 'B', 10),
]
>>> sorted(student_tuples, key=lambda student: student[2]) # sort by age
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The same technique works for objects with named attributes. For example:

```
>>> class Student:
    def __init__(self, name, grade, age):
        self.name = name
        self.grade = grade
        self.age = age
    def __repr__(self):
        return repr((self.name, self.grade, self.age))

>>> student_objects = [
    Student('john', 'A', 15),
    Student('jane', 'B', 12),
    Student('dave', 'B', 10),
]
>>> sorted(student_objects, key=lambda student: student.age) # sort by age
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

## 3 Operator Module Functions

The key-function patterns shown above are very common, so Python provides convenience functions to make accessor functions easier and faster. The operator module has `operator.itemgetter()`, `operator.attrgetter()`, and starting in Python 2.5 a `operator.methodcaller()` function.

Using those functions, the above examples become simpler and faster:

```
>>> from operator import itemgetter, attrgetter
>>> sorted(student_tuples, key=itemgetter(2))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
>>> sorted(student_objects, key=attrgetter('age'))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The operator module functions allow multiple levels of sorting. For example, to sort by *grade* then by *age*:

```
>>> sorted(student_tuples, key=itemgetter(1,2))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]
>>> sorted(student_objects, key=attrgetter('grade', 'age'))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]
```

The `operator.methodcaller()` function makes method calls with fixed parameters for each object being sorted. For example, the `str.count()` method could be used to compute message priority by counting the number of exclamation marks in a message:

```
>>> messages = ['critical!!!', 'hurry!', 'standby', 'immediate!!!']
>>> sorted(messages, key=methodcaller('count', '!'))
['standby', 'hurry!', 'immediate!!!', 'critical!!!']
```

## 4 Ascending and Descending

Both `list.sort()` and `sorted()` accept a *reverse* parameter with a boolean value. This is used to flag descending sorts. For example, to get the student data in reverse *age* order:

```
>>> sorted(student_tuples, key=itemgetter(2), reverse=True)
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
>>> sorted(student_objects, key=attrgetter('age'), reverse=True)
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

## 5 Sort Stability and Complex Sorts

Starting with Python 2.2, sorts are guaranteed to be *stable*. That means that when multiple records have the same key, their original order is preserved.

```
>>> data = [('red', 1), ('blue', 1), ('red', 2), ('blue', 2)]
>>> sorted(data, key=itemgetter(0))
[('blue', 1), ('blue', 2), ('red', 1), ('red', 2)]
```

Notice how the two records for *blue* retain their original order so that `('blue', 1)` is guaranteed to precede `('blue', 2)`.

This wonderful property lets you build complex sorts in a series of sorting steps. For example, to sort the student data by descending *grade* and then ascending *age*, do the *age* sort first and then sort again using *grade*:

```
>>> s = sorted(student_objects, key=attrgetter('age'))           # sort on secondary key
>>> sorted(s, key=attrgetter('grade'), reverse=True)          # now sort on primary key, desc
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The `Timsort` algorithm used in Python does multiple sorts efficiently because it can take advantage of any ordering already present in a dataset.

## 6 The Old Way Using Decorate-Sort-Undecorate

This idiom is called Decorate-Sort-Undecorate after its three steps:

- First, the initial list is decorated with new values that control the sort order.
- Second, the decorated list is sorted.
- Finally, the decorations are removed, creating a list that contains only the initial values in the new order.

For example, to sort the student data by *grade* using the DSU approach:

```
>>> decorated = [(student.grade, i, student) for i, student in enumerate(student_objects)]
>>> decorated.sort()
>>> [student for grade, i, student in decorated]                # undecorate
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

This idiom works because tuples are compared lexicographically; the first items are compared; if they are the same then the second items are compared, and so on.

It is not strictly necessary in all cases to include the index *i* in the decorated list, but including it gives two benefits:

- The sort is stable – if two items have the same key, their order will be preserved in the sorted list.
- The original items do not have to be comparable because the ordering of the decorated tuples will be determined by at most the first two items. So for example the original list could contain complex numbers which cannot be sorted directly.

Another name for this idiom is `Schwartzian transform`, after Randal L. Schwartz, who popularized it among Perl programmers.

For large lists and lists where the comparison information is expensive to calculate, and Python versions before 2.4, DSU is likely to be the fastest way to sort the list. For 2.4 and later, key functions provide the same functionality.

## 7 The Old Way Using the `cmp` Parameter

Many constructs given in this HOWTO assume Python 2.4 or later. Before that, there was no `sorted()` builtin and `list.sort()` took no keyword arguments. Instead, all of the Py2.x versions supported a `cmp` parameter to handle user specified comparison functions.

In Python 3, the `cmp` parameter was removed entirely (as part of a larger effort to simplify and unify the language, eliminating the conflict between rich comparisons and the `__cmp__()` magic method).

In Python 2, `sort()` allowed an optional function which can be called for doing the comparisons. That function should take two arguments to be compared and then return a negative value for less-than, return zero if they are equal, or return a positive value for greater-than. For example, we can do:

```
>>> def numeric_compare(x, y):
    return x - y
>>> sorted([5, 2, 4, 1, 3], cmp=numeric_compare)
[1, 2, 3, 4, 5]
```

Or you can reverse the order of comparison with:

```
>>> def reverse_numeric(x, y):
    return y - x
>>> sorted([5, 2, 4, 1, 3], cmp=reverse_numeric)
[5, 4, 3, 2, 1]
```

When porting code from Python 2.x to 3.x, the situation can arise when you have the user supplying a comparison function and you need to convert that to a key function. The following wrapper makes that easy to do:

```
def cmp_to_key(mycmp):
    'Convert a cmp= function into a key= function'
    class K(object):
        def __init__(self, obj, *args):
            self.obj = obj
        def __lt__(self, other):
            return mycmp(self.obj, other.obj) < 0
        def __gt__(self, other):
            return mycmp(self.obj, other.obj) > 0
        def __eq__(self, other):
            return mycmp(self.obj, other.obj) == 0
        def __le__(self, other):
            return mycmp(self.obj, other.obj) <= 0
        def __ge__(self, other):
            return mycmp(self.obj, other.obj) >= 0
        def __ne__(self, other):
            return mycmp(self.obj, other.obj) != 0
    return K
```

To convert to a key function, just wrap the old comparison function:

```
>>> sorted([5, 2, 4, 1, 3], key=cmp_to_key(reverse_numeric))
[5, 4, 3, 2, 1]
```

In Python 2.7, the `functools.cmp_to_key()` function was added to the `functools` module.

## 8 Odd and Ends

- For locale aware sorting, use `locale.strxfrm()` for a key function or `locale.strcoll()` for a comparison function.
- The `reverse` parameter still maintains sort stability (so that records with equal keys retain their original order). Interestingly, that effect can be simulated without the parameter by using the builtin `reversed()` function twice:

```
>>> data = [('red', 1), ('blue', 1), ('red', 2), ('blue', 2)]
>>> assert sorted(data, reverse=True) == list(reversed(sorted(reversed(data))))
```

- To create a standard sort order for a class, just add the appropriate rich comparison methods:

```
>>> Student.__eq__ = lambda self, other: self.age == other.age
>>> Student.__ne__ = lambda self, other: self.age != other.age
>>> Student.__lt__ = lambda self, other: self.age < other.age
>>> Student.__le__ = lambda self, other: self.age <= other.age
>>> Student.__gt__ = lambda self, other: self.age > other.age
>>> Student.__ge__ = lambda self, other: self.age >= other.age
```

```
>>> sorted(student_objects)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

For general purpose comparisons, the recommended approach is to define all six rich comparison operators. The `functools.total_ordering()` class decorator makes this easy to implement.

- Key functions need not depend directly on the objects being sorted. A key function can also access external resources. For instance, if the student grades are stored in a dictionary, they can be used to sort a separate list of student names:

```
>>> students = ['dave', 'john', 'jane']
>>> grades = {'john': 'F', 'jane': 'A', 'dave': 'C'}
>>> sorted(students, key=grades.__getitem__)
['jane', 'dave', 'john']
```

---

# Unicode HOWTO

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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### Release 1.03

This HOWTO discusses Python 2.x's support for Unicode, and explains various problems that people commonly encounter when trying to work with Unicode. (This HOWTO has not yet been updated to cover the 3.x versions of Python.)

# 1 Introduction to Unicode

## 1.1 History of Character Codes

In 1968, the American Standard Code for Information Interchange, better known by its acronym ASCII, was standardized. ASCII defined numeric codes for various characters, with the numeric values running from 0 to 127. For example, the lowercase letter 'a' is assigned 97 as its code value.

ASCII was an American-developed standard, so it only defined unaccented characters. There was an 'e', but no 'é' or 'Ï'. This meant that languages which required accented characters couldn't be faithfully represented in ASCII. (Actually the missing accents matter for English, too, which contains words such as 'naïve' and 'café', and some publications have house styles which require spellings such as 'coöperate'.)

For a while people just wrote programs that didn't display accents. I remember looking at Apple ][ BASIC programs, published in French-language publications in the mid-1980s, that had lines like these:

```
PRINT "FICHER EST COMPLETE."  
PRINT "CARACTERE NON ACCEPTE."
```

Those messages should contain accents, and they just look wrong to someone who can read French.

In the 1980s, almost all personal computers were 8-bit, meaning that bytes could hold values ranging from 0 to 255. ASCII codes only went up to 127, so some machines assigned values between 128 and 255 to accented characters. Different machines had different codes, however, which led to problems exchanging files. Eventually various commonly used sets of values for the 128-255 range emerged. Some were true standards, defined by the International Standards Organization, and some were **de facto** conventions that were invented by one company or another and managed to catch on.

255 characters aren't very many. For example, you can't fit both the accented characters used in Western Europe and the Cyrillic alphabet used for Russian into the 128-255 range because there are more than 127 such characters.

You could write files using different codes (all your Russian files in a coding system called KOI8, all your French files in a different coding system called Latin1), but what if you wanted to write a French document that quotes some Russian text? In the 1980s people began to want to solve this problem, and the Unicode standardization effort began.

Unicode started out using 16-bit characters instead of 8-bit characters. 16 bits means you have  $2^{16} = 65,536$  distinct values available, making it possible to represent many different characters from many different alphabets; an initial goal was to have Unicode contain the alphabets for every single human language. It turns out that even 16 bits isn't enough to meet that goal, and the modern Unicode specification uses a wider range of codes, 0-1,114,111 (0x10ffff in base-16).

There's a related ISO standard, ISO 10646. Unicode and ISO 10646 were originally separate efforts, but the specifications were merged with the 1.1 revision of Unicode.

(This discussion of Unicode's history is highly simplified. I don't think the average Python programmer needs to worry about the historical details; consult the Unicode consortium site listed in the References for more information.)

## 1.2 Definitions

A **character** is the smallest possible component of a text. 'A', 'B', 'C', etc., are all different characters. So are 'È' and 'Ï'. Characters are abstractions, and vary depending on the language or context you're talking about. For example, the symbol for ohms ( $\Omega$ ) is usually drawn much like the capital letter omega ( $\Omega$ ) in the Greek alphabet (they may even be the same in some fonts), but these are two different characters that have different meanings.

The Unicode standard describes how characters are represented by **code points**. A code point is an integer value, usually denoted in base 16. In the standard, a code point is written using the notation U+12ca to mean the character with

value 0x12ca (4810 decimal). The Unicode standard contains a lot of tables listing characters and their corresponding code points:

```
0061    ' a ' ; LATIN SMALL LETTER A
0062    ' b ' ; LATIN SMALL LETTER B
0063    ' c ' ; LATIN SMALL LETTER C
...
007B    ' { ' ; LEFT CURLY BRACKET
```

Strictly, these definitions imply that it's meaningless to say 'this is character U+12ca'. U+12ca is a code point, which represents some particular character; in this case, it represents the character 'ETHIOPIC SYLLABLE WI'. In informal contexts, this distinction between code points and characters will sometimes be forgotten.

A character is represented on a screen or on paper by a set of graphical elements that's called a **glyph**. The glyph for an uppercase A, for example, is two diagonal strokes and a horizontal stroke, though the exact details will depend on the font being used. Most Python code doesn't need to worry about glyphs; figuring out the correct glyph to display is generally the job of a GUI toolkit or a terminal's font renderer.

### 1.3 Encodings

To summarize the previous section: a Unicode string is a sequence of code points, which are numbers from 0 to 0x10ffff. This sequence needs to be represented as a set of bytes (meaning, values from 0-255) in memory. The rules for translating a Unicode string into a sequence of bytes are called an **encoding**.

The first encoding you might think of is an array of 32-bit integers. In this representation, the string "Python" would look like this:

```
      P           y           t           h           o           n
0x50 00 00 00 79 00 00 00 74 00 00 00 68 00 00 00 6f 00 00 00 6e 00 00 00
    0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
```

This representation is straightforward but using it presents a number of problems.

1. It's not portable; different processors order the bytes differently.
2. It's very wasteful of space. In most texts, the majority of the code points are less than 127, or less than 255, so a lot of space is occupied by zero bytes. The above string takes 24 bytes compared to the 6 bytes needed for an ASCII representation. Increased RAM usage doesn't matter too much (desktop computers have megabytes of RAM, and strings aren't usually that large), but expanding our usage of disk and network bandwidth by a factor of 4 is intolerable.
3. It's not compatible with existing C functions such as `strlen()`, so a new family of wide string functions would need to be used.
4. Many Internet standards are defined in terms of textual data, and can't handle content with embedded zero bytes.

Generally people don't use this encoding, instead choosing other encodings that are more efficient and convenient. UTF-8 is probably the most commonly supported encoding; it will be discussed below.

Encodings don't have to handle every possible Unicode character, and most encodings don't. For example, Python's default encoding is the 'ascii' encoding. The rules for converting a Unicode string into the ASCII encoding are simple; for each code point:

1. If the code point is < 128, each byte is the same as the value of the code point.
2. If the code point is 128 or greater, the Unicode string can't be represented in this encoding. (Python raises a `UnicodeEncodeError` exception in this case.)

Latin-1, also known as ISO-8859-1, is a similar encoding. Unicode code points 0-255 are identical to the Latin-1 values, so converting to this encoding simply requires converting code points to byte values; if a code point larger than 255 is encountered, the string can't be encoded into Latin-1.

Encodings don't have to be simple one-to-one mappings like Latin-1. Consider IBM's EBCDIC, which was used on IBM mainframes. Letter values weren't in one block: 'a' through 'i' had values from 129 to 137, but 'j' through 'r' were 145 through 153. If you wanted to use EBCDIC as an encoding, you'd probably use some sort of lookup table to perform the conversion, but this is largely an internal detail.

UTF-8 is one of the most commonly used encodings. UTF stands for "Unicode Transformation Format", and the '8' means that 8-bit numbers are used in the encoding. (There's also a UTF-16 encoding, but it's less frequently used than UTF-8.) UTF-8 uses the following rules:

1. If the code point is <128, it's represented by the corresponding byte value.
2. If the code point is between 128 and 0x7ff, it's turned into two byte values between 128 and 255.
3. Code points >0x7ff are turned into three- or four-byte sequences, where each byte of the sequence is between 128 and 255.

UTF-8 has several convenient properties:

1. It can handle any Unicode code point.
2. A Unicode string is turned into a string of bytes containing no embedded zero bytes. This avoids byte-ordering issues, and means UTF-8 strings can be processed by C functions such as `strcpy()` and sent through protocols that can't handle zero bytes.
3. A string of ASCII text is also valid UTF-8 text.
4. UTF-8 is fairly compact; the majority of code points are turned into two bytes, and values less than 128 occupy only a single byte.
5. If bytes are corrupted or lost, it's possible to determine the start of the next UTF-8-encoded code point and resynchronize. It's also unlikely that random 8-bit data will look like valid UTF-8.

## 1.4 References

The Unicode Consortium site at <http://www.unicode.org> has character charts, a glossary, and PDF versions of the Unicode specification. Be prepared for some difficult reading. <http://www.unicode.org/history/> is a chronology of the origin and development of Unicode.

To help understand the standard, Jukka Korpela has written an introductory guide to reading the Unicode character tables, available at <http://www.cs.tut.fi/~jkorpela/unicode/guide.html>.

Another good introductory article was written by Joel Spolsky <http://www.joelonsoftware.com/articles/Unicode.html>. If this introduction didn't make things clear to you, you should try reading this alternate article before continuing.

Wikipedia entries are often helpful; see the entries for "character encoding" [http://en.wikipedia.org/wiki/Character\\_encoding](http://en.wikipedia.org/wiki/Character_encoding) and UTF-8 <http://en.wikipedia.org/wiki/UTF-8>, for example.

## 2 Python 2.x's Unicode Support

Now that you've learned the rudiments of Unicode, we can look at Python's Unicode features.

### 2.1 The Unicode Type

Unicode strings are expressed as instances of the `unicode` type, one of Python's repertoire of built-in types. It derives from an abstract type called `basestring`, which is also an ancestor of the `str` type; you can therefore check if a value is a string type with `isinstance(value, basestring)`. Under the hood, Python represents Unicode strings as either 16- or 32-bit integers, depending on how the Python interpreter was compiled.

The `unicode()` constructor has the signature `unicode(string[, encoding, errors])`. All of its arguments should be 8-bit strings. The first argument is converted to Unicode using the specified encoding; if you leave off the encoding argument, the ASCII encoding is used for the conversion, so characters greater than 127 will be treated as errors:

```
>>> unicode('abcdef')
u'abcdef'
>>> s = unicode('abcdef')
>>> type(s)
<type 'unicode'>
>>> unicode('abcdef' + chr(255))
Traceback (most recent call last):
...
UnicodeDecodeError: 'ascii' codec can't decode byte 0xff in position 6:
ordinal not in range(128)
```

The `errors` argument specifies the response when the input string can't be converted according to the encoding's rules. Legal values for this argument are 'strict' (raise a `UnicodeDecodeError` exception), 'replace' (add U+FFFD, 'REPLACEMENT CHARACTER'), or 'ignore' (just leave the character out of the Unicode result). The following examples show the differences:

```
>>> unicode('\x80abc', errors='strict')
Traceback (most recent call last):
...
UnicodeDecodeError: 'ascii' codec can't decode byte 0x80 in position 0:
ordinal not in range(128)
>>> unicode('\x80abc', errors='replace')
u'\ufffdabc'
>>> unicode('\x80abc', errors='ignore')
u'abc'
```

Encodings are specified as strings containing the encoding's name. Python 2.7 comes with roughly 100 different encodings; see the Python Library Reference at *standard-encodings* for a list. Some encodings have multiple names; for example, 'latin-1', 'iso\_8859\_1' and '8859' are all synonyms for the same encoding.

One-character Unicode strings can also be created with the `unichr()` built-in function, which takes integers and returns a Unicode string of length 1 that contains the corresponding code point. The reverse operation is the built-in `ord()` function that takes a one-character Unicode string and returns the code point value:

```
>>> unichr(40960)
u'\ua000'
>>> ord(u'\ua000')
40960
```

Instances of the `unicode` type have many of the same methods as the 8-bit string type for operations such as searching and formatting:

```
>>> s = u'Was ever feather so lightly blown to and fro as this multitude?'
>>> s.count('e')
5
>>> s.find('feather')
9
>>> s.find('bird')
-1
>>> s.replace('feather', 'sand')
u'Was ever sand so lightly blown to and fro as this multitude?'
>>> s.upper()
u'WAS EVER FEATHER SO LIGHTLY BLOWN TO AND FRO AS THIS MULTITUDE?'
```

Note that the arguments to these methods can be Unicode strings or 8-bit strings. 8-bit strings will be converted to Unicode before carrying out the operation; Python's default ASCII encoding will be used, so characters greater than 127 will cause an exception:

```
>>> s.find('Was\x9f')
Traceback (most recent call last):
...
UnicodeDecodeError: 'ascii' codec can't decode byte 0x9f in position 3:
ordinal not in range(128)
>>> s.find(u'Was\x9f')
-1
```

Much Python code that operates on strings will therefore work with Unicode strings without requiring any changes to the code. (Input and output code needs more updating for Unicode; more on this later.)

Another important method is `.encode([encoding], [errors='strict'])`, which returns an 8-bit string version of the Unicode string, encoded in the requested encoding. The `errors` parameter is the same as the parameter of the `unicode()` constructor, with one additional possibility; as well as 'strict', 'ignore', and 'replace', you can also pass 'xmlcharrefreplace' which uses XML's character references. The following example shows the different results:

```
>>> u = unichr(40960) + u'abcd' + unichr(1972)
>>> u.encode('utf-8')
'\xea\x80\x80abcd\xde\xb4'
>>> u.encode('ascii')
Traceback (most recent call last):
...
UnicodeEncodeError: 'ascii' codec can't encode character u'\ua000' in
position 0: ordinal not in range(128)
>>> u.encode('ascii', 'ignore')
'abcd'
>>> u.encode('ascii', 'replace')
'?abcd?'
>>> u.encode('ascii', 'xmlcharrefreplace')
'&#40960;abcd&#1972;'
```

Python's 8-bit strings have a `.decode([encoding], [errors])` method that interprets the string using the given encoding:

```
>>> u = unichr(40960) + u'abcd' + unichr(1972)      # Assemble a string
>>> utf8_version = u.encode('utf-8')                 # Encode as UTF-8
>>> type(utf8_version), utf8_version
(<type 'str'>, '\xea\x80\x80abcd\xde\xb4')
>>> u2 = utf8_version.decode('utf-8')                 # Decode using UTF-8
>>> u == u2                                           # The two strings match
True
```

The low-level routines for registering and accessing the available encodings are found in the `codecs` module. However, the encoding and decoding functions returned by this module are usually more low-level than is comfortable, so I'm not going to describe the `codecs` module here. If you need to implement a completely new encoding, you'll need to learn about the `codecs` module interfaces, but implementing encodings is a specialized task that also won't be covered here. Consult the Python documentation to learn more about this module.

The most commonly used part of the `codecs` module is the `codecs.open()` function which will be discussed in the section on input and output.

## 2.2 Unicode Literals in Python Source Code

In Python source code, Unicode literals are written as strings prefixed with the 'u' or 'U' character: `u'abcdefghijklmnopq'`. Specific code points can be written using the `\u` escape sequence, which is followed by four hex digits giving the code point. The `\U` escape sequence is similar, but expects 8 hex digits, not 4.

Unicode literals can also use the same escape sequences as 8-bit strings, including `\x`, but `\x` only takes two hex digits so it can't express an arbitrary code point. Octal escapes can go up to `U+01ff`, which is octal 777.

```
>>> s = u"a\xac\u1234\u20ac\U00008000"
... #      ^^^^ two-digit hex escape
... #      ^^^^^^ four-digit Unicode escape
... #      ^^^^^^^^^^^ eight-digit Unicode escape
>>> for c in s: print ord(c),
...
97 172 4660 8364 32768
```

Using escape sequences for code points greater than 127 is fine in small doses, but becomes an annoyance if you're using many accented characters, as you would in a program with messages in French or some other accent-using language. You can also assemble strings using the `unichr()` built-in function, but this is even more tedious.

Ideally, you'd want to be able to write literals in your language's natural encoding. You could then edit Python source code with your favorite editor which would display the accented characters naturally, and have the right characters used at runtime.

Python supports writing Unicode literals in any encoding, but you have to declare the encoding being used. This is done by including a special comment as either the first or second line of the source file:

```
#!/usr/bin/env python
# -*- coding: latin-1 -*-

u = u'abcdé'
print ord(u[-1])
```

The syntax is inspired by Emacs's notation for specifying variables local to a file. Emacs supports many different variables, but Python only supports 'coding'. The  `-*-`  symbols indicate to Emacs that the comment is special; they have no significance to Python but are a convention. Python looks for `coding: name` or `coding=name` in the comment.

If you don't include such a comment, the default encoding used will be ASCII. Versions of Python before 2.4 were Euro-centric and assumed Latin-1 as a default encoding for string literals; in Python 2.4, characters greater than 127 still work but result in a warning. For example, the following program has no encoding declaration:

```
#!/usr/bin/env python
u = u'abcdé'
print ord(u[-1])
```

When you run it with Python 2.4, it will output the following warning:

```
amk:~$ python2.4 p263.py
sys:1: DeprecationWarning: Non-ASCII character '\xe9'
      in file p263.py on line 2, but no encoding declared;
      see http://www.python.org/peps/pep-0263.html for details
```

Python 2.5 and higher are stricter and will produce a syntax error:

```
amk:~$ python2.5 p263.py
File "/tmp/p263.py", line 2
SyntaxError: Non-ASCII character '\xc3' in file /tmp/p263.py
```

on line 2, but no encoding declared; see <http://www.python.org/peps/pep-0263.html> for details

## 2.3 Unicode Properties

The Unicode specification includes a database of information about code points. For each code point that's defined, the information includes the character's name, its category, the numeric value if applicable (Unicode has characters representing the Roman numerals and fractions such as one-third and four-fifths). There are also properties related to the code point's use in bidirectional text and other display-related properties.

The following program displays some information about several characters, and prints the numeric value of one particular character:

```
import unicodedata

u = unichr(233) + unichr(0x0bf2) + unichr(3972) + unichr(6000) + unichr(13231)

for i, c in enumerate(u):
    print i, '%04x' % ord(c), unicodedata.category(c),
    print unicodedata.name(c)

# Get numeric value of second character
print unicodedata.numeric(u[1])
```

When run, this prints:

```
0 00e9 Ll LATIN SMALL LETTER E WITH ACUTE
1 0bf2 No TAMIL NUMBER ONE THOUSAND
2 0f84 Mn TIBETAN MARK HALANTA
3 1770 Lo TAGBANWA LETTER SA
4 33af So SQUARE RAD OVER S SQUARED
1000.0
```

The category codes are abbreviations describing the nature of the character. These are grouped into categories such as “Letter”, “Number”, “Punctuation”, or “Symbol”, which in turn are broken up into subcategories. To take the codes from the above output, ‘Ll’ means ‘Letter, lowercase’, ‘No’ means “Number, other”, ‘Mn’ is “Mark, nonspacing”, and ‘So’ is “Symbol, other”. See [http://www.unicode.org/reports/tr44/#General\\_Category\\_Values](http://www.unicode.org/reports/tr44/#General_Category_Values) for a list of category codes.

## 2.4 References

The Unicode and 8-bit string types are described in the Python library reference at *typesseq*.

The documentation for the `unicodedata` module.

The documentation for the `codecs` module.

Marc-André Lemburg gave a presentation at EuroPython 2002 titled “Python and Unicode”. A PDF version of his slides is available at <http://downloads.egenix.com/python/Unicode-EPC2002-Talk.pdf>, and is an excellent overview of the design of Python’s Unicode features.

## 3 Reading and Writing Unicode Data

Once you’ve written some code that works with Unicode data, the next problem is input/output. How do you get Unicode strings into your program, and how do you convert Unicode into a form suitable for storage or transmission?

It's possible that you may not need to do anything depending on your input sources and output destinations; you should check whether the libraries used in your application support Unicode natively. XML parsers often return Unicode data, for example. Many relational databases also support Unicode-valued columns and can return Unicode values from an SQL query.

Unicode data is usually converted to a particular encoding before it gets written to disk or sent over a socket. It's possible to do all the work yourself: open a file, read an 8-bit string from it, and convert the string with `unicode(str, encoding)`. However, the manual approach is not recommended.

One problem is the multi-byte nature of encodings; one Unicode character can be represented by several bytes. If you want to read the file in arbitrary-sized chunks (say, 1K or 4K), you need to write error-handling code to catch the case where only part of the bytes encoding a single Unicode character are read at the end of a chunk. One solution would be to read the entire file into memory and then perform the decoding, but that prevents you from working with files that are extremely large; if you need to read a 2Gb file, you need 2Gb of RAM. (More, really, since for at least a moment you'd need to have both the encoded string and its Unicode version in memory.)

The solution would be to use the low-level decoding interface to catch the case of partial coding sequences. The work of implementing this has already been done for you: the `codecs` module includes a version of the `open()` function that returns a file-like object that assumes the file's contents are in a specified encoding and accepts Unicode parameters for methods such as `.read()` and `.write()`.

The function's parameters are `open(filename, mode='rb', encoding=None, errors='strict', buffering=1)`. `mode` can be `'r'`, `'w'`, or `'a'`, just like the corresponding parameter to the regular built-in `open()` function; add a `'+'` to update the file. `buffering` is similarly parallel to the standard function's parameter. `encoding` is a string giving the encoding to use; if it's left as `None`, a regular Python file object that accepts 8-bit strings is returned. Otherwise, a wrapper object is returned, and data written to or read from the wrapper object will be converted as needed. `errors` specifies the action for encoding errors and can be one of the usual values of `'strict'`, `'ignore'`, and `'replace'`.

Reading Unicode from a file is therefore simple:

```
import codecs
f = codecs.open('unicode.rst', encoding='utf-8')
for line in f:
    print repr(line)
```

It's also possible to open files in update mode, allowing both reading and writing:

```
f = codecs.open('test', encoding='utf-8', mode='w+')
f.write(u'\u4500 blah blah blah\n')
f.seek(0)
print repr(f.readline()[:1])
f.close()
```

Unicode character U+FEFF is used as a byte-order mark (BOM), and is often written as the first character of a file in order to assist with autodetection of the file's byte ordering. Some encodings, such as UTF-16, expect a BOM to be present at the start of a file; when such an encoding is used, the BOM will be automatically written as the first character and will be silently dropped when the file is read. There are variants of these encodings, such as `'utf-16-le'` and `'utf-16-be'` for little-endian and big-endian encodings, that specify one particular byte ordering and don't skip the BOM.

## 3.1 Unicode filenames

Most of the operating systems in common use today support filenames that contain arbitrary Unicode characters. Usually this is implemented by converting the Unicode string into some encoding that varies depending on the system. For example, Mac OS X uses UTF-8 while Windows uses a configurable encoding; on Windows, Python uses the name "mbcs" to refer to whatever the currently configured encoding is. On Unix systems, there will only be a filesystem encoding if you've set the `LANG` or `LC_CTYPE` environment variables; if you haven't, the default encoding is ASCII.

The `sys.getfilesystemencoding()` function returns the encoding to use on your current system, in case you want to do the encoding manually, but there's not much reason to bother. When opening a file for reading or writing, you can usually just provide the Unicode string as the filename, and it will be automatically converted to the right encoding for you:

```
filename = u'filename\u4500abc'
f = open(filename, 'w')
f.write('blah\n')
f.close()
```

Functions in the `os` module such as `os.stat()` will also accept Unicode filenames.

`os.listdir()`, which returns filenames, raises an issue: should it return the Unicode version of filenames, or should it return 8-bit strings containing the encoded versions? `os.listdir()` will do both, depending on whether you provided the directory path as an 8-bit string or a Unicode string. If you pass a Unicode string as the path, filenames will be decoded using the filesystem's encoding and a list of Unicode strings will be returned, while passing an 8-bit path will return the 8-bit versions of the filenames. For example, assuming the default filesystem encoding is UTF-8, running the following program:

```
fn = u'filename\u4500abc'
f = open(fn, 'w')
f.close()
```

```
import os
print os.listdir('.')
print os.listdir(u'.')
```

will produce the following output:

```
amk:~$ python t.py
['.svn', 'filename\xe4\x94\x80abc', ...]
[u'.svn', u'filename\u4500abc', ...]
```

The first list contains UTF-8-encoded filenames, and the second list contains the Unicode versions.

## 3.2 Tips for Writing Unicode-aware Programs

This section provides some suggestions on writing software that deals with Unicode.

The most important tip is:

Software should only work with Unicode strings internally, converting to a particular encoding on output.

If you attempt to write processing functions that accept both Unicode and 8-bit strings, you will find your program vulnerable to bugs wherever you combine the two different kinds of strings. Python's default encoding is ASCII, so whenever a character with an ASCII value > 127 is in the input data, you'll get a `UnicodeDecodeError` because that character can't be handled by the ASCII encoding.

It's easy to miss such problems if you only test your software with data that doesn't contain any accents; everything will seem to work, but there's actually a bug in your program waiting for the first user who attempts to use characters > 127. A second tip, therefore, is:

Include characters > 127 and, even better, characters > 255 in your test data.

When using data coming from a web browser or some other untrusted source, a common technique is to check for illegal characters in a string before using the string in a generated command line or storing it in a database. If you're doing this, be careful to check the string once it's in the form that will be used or stored; it's possible for encodings to be used to disguise characters. This is especially true if the input data also specifies the encoding; many encodings leave the commonly checked-for characters alone, but Python includes some encodings such as `'base64'` that modify every single character.

For example, let's say you have a content management system that takes a Unicode filename, and you want to disallow paths with a '/' character. You might write this code:

```
def read_file (filename, encoding):
    if '/' in filename:
        raise ValueError("'/' not allowed in filenames")
    unicode_name = filename.decode(encoding)
    f = open(unicode_name, 'r')
    # ... return contents of file ...
```

However, if an attacker could specify the 'base64' encoding, they could pass 'L2V0Yy9wYXNzd2Q=', which is the base-64 encoded form of the string '/etc/passwd', to read a system file. The above code looks for '/' characters in the encoded form and misses the dangerous character in the resulting decoded form.

### 3.3 References

The PDF slides for Marc-André Lemburg's presentation "Writing Unicode-aware Applications in Python" are available at <<http://downloads.egenix.com/python/LSM2005-Developing-Unicode-aware-applications-in-Python.pdf>> and discuss questions of character encodings as well as how to internationalize and localize an application.

## 4 Revision History and Acknowledgements

Thanks to the following people who have noted errors or offered suggestions on this article: Nicholas Bastin, Marius Gedminas, Kent Johnson, Ken Krugler, Marc-André Lemburg, Martin von Löwis, Chad Whitacre.

Version 1.0: posted August 5 2005.

Version 1.01: posted August 7 2005. Corrects factual and markup errors; adds several links.

Version 1.02: posted August 16 2005. Corrects factual errors.

Version 1.03: posted June 20 2010. Notes that Python 3.x is not covered, and that the HOWTO only covers 2.x.

---

# HOWTO Fetch Internet Resources Using urllib2

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Michael Foord

**Note:** There is an French translation of an earlier revision of this HOWTO, available at [urllib2 - Le Manuel manquant](http://urllib2 - Le Manuel manquant).

---

# 1 Introduction

## Related Articles

You may also find useful the following article on fetching web resources with Python :

- [Basic Authentication](#)

A tutorial on *Basic Authentication*, with examples in Python.

`urllib2` is a [Python](#) module for fetching URLs (Uniform Resource Locators). It offers a very simple interface, in the form of the `urlopen` function. This is capable of fetching URLs using a variety of different protocols. It also offers a slightly more complex interface for handling common situations - like basic authentication, cookies, proxies and so on. These are provided by objects called handlers and openers.

`urllib2` supports fetching URLs for many “URL schemes” (identified by the string before the “:” in URL - for example “ftp” is the URL scheme of “<ftp://python.org>”) using their associated network protocols (e.g. FTP, HTTP). This tutorial focuses on the most common case, HTTP.

For straightforward situations `urlopen` is very easy to use. But as soon as you encounter errors or non-trivial cases when opening HTTP URLs, you will need some understanding of the HyperText Transfer Protocol. The most comprehensive and authoritative reference to HTTP is [RFC 2616](#). This is a technical document and not intended to be easy to read. This HOWTO aims to illustrate using `urllib2`, with enough detail about HTTP to help you through. It is not intended to replace the `urllib2` docs, but is supplementary to them.

## 2 Fetching URLs

The simplest way to use `urllib2` is as follows:

```
import urllib2
response = urllib2.urlopen('http://python.org/')
html = response.read()
```

Many uses of `urllib2` will be that simple (note that instead of an ‘http:’ URL we could have used an URL starting with ‘ftp:’, ‘file:’, etc.). However, it’s the purpose of this tutorial to explain the more complicated cases, concentrating on HTTP.

HTTP is based on requests and responses - the client makes requests and servers send responses. `urllib2` mirrors this with a `Request` object which represents the HTTP request you are making. In its simplest form you create a `Request` object that specifies the URL you want to fetch. Calling `urlopen` with this `Request` object returns a response object for the URL requested. This response is a file-like object, which means you can for example call `.read()` on the response:

```
import urllib2

req = urllib2.Request('http://www.voidspace.org.uk')
response = urllib2.urlopen(req)
the_page = response.read()
```

Note that `urllib2` makes use of the same `Request` interface to handle all URL schemes. For example, you can make an FTP request like so:

```
req = urllib2.Request('ftp://example.com/')
```

In the case of HTTP, there are two extra things that Request objects allow you to do: First, you can pass data to be sent to the server. Second, you can pass extra information (“metadata”) *about* the data or the about request itself, to the server - this information is sent as HTTP “headers”. Let’s look at each of these in turn.

## 2.1 Data

Sometimes you want to send data to a URL (often the URL will refer to a CGI (Common Gateway Interface) script<sup>1</sup> or other web application). With HTTP, this is often done using what’s known as a **POST** request. This is often what your browser does when you submit a HTML form that you filled in on the web. Not all POSTs have to come from forms: you can use a POST to transmit arbitrary data to your own application. In the common case of HTML forms, the data needs to be encoded in a standard way, and then passed to the Request object as the `data` argument. The encoding is done using a function from the `urllib` library *not* from `urllib2`.

```
import urllib
import urllib2
```

```
url = 'http://www.someserver.com/cgi-bin/register.cgi'
values = {'name' : 'Michael Foord',
          'location' : 'Northampton',
          'language' : 'Python' }
```

```
data = urllib.urlencode(values)
req = urllib2.Request(url, data)
response = urllib2.urlopen(req)
the_page = response.read()
```

Note that other encodings are sometimes required (e.g. for file upload from HTML forms - see [HTML Specification, Form Submission](#) for more details).

If you do not pass the `data` argument, `urllib2` uses a **GET** request. One way in which GET and POST requests differ is that POST requests often have “side-effects”: they change the state of the system in some way (for example by placing an order with the website for a hundredweight of tinned spam to be delivered to your door). Though the HTTP standard makes it clear that POSTs are intended to *always* cause side-effects, and GET requests *never* to cause side-effects, nothing prevents a GET request from having side-effects, nor a POST requests from having no side-effects. Data can also be passed in an HTTP GET request by encoding it in the URL itself.

This is done as follows:

```
>>> import urllib2
>>> import urllib
>>> data = {}
>>> data['name'] = 'Somebody Here'
>>> data['location'] = 'Northampton'
>>> data['language'] = 'Python'
>>> url_values = urllib.urlencode(data)
>>> print url_values
name=Somebody+Here&language=Python&location=Northampton
>>> url = 'http://www.example.com/example.cgi'
>>> full_url = url + '?' + url_values
>>> data = urllib2.urlopen(full_url)
```

Notice that the full URL is created by adding a `?` to the URL, followed by the encoded values.

---

<sup>1</sup> For an introduction to the CGI protocol see [Writing Web Applications in Python](#).

## 2.2 Headers

We'll discuss here one particular HTTP header, to illustrate how to add headers to your HTTP request.

Some websites <sup>2</sup> dislike being browsed by programs, or send different versions to different browsers <sup>3</sup>. By default `urllib2` identifies itself as `Python-urllib/x.y` (where `x` and `y` are the major and minor version numbers of the Python release, e.g. `Python-urllib/2.5`), which may confuse the site, or just plain not work. The way a browser identifies itself is through the `User-Agent` header <sup>4</sup>. When you create a `Request` object you can pass a dictionary of headers in. The following example makes the same request as above, but identifies itself as a version of Internet Explorer <sup>5</sup>.

```
import urllib
import urllib2

url = 'http://www.someserver.com/cgi-bin/register.cgi'
user_agent = 'Mozilla/4.0 (compatible; MSIE 5.5; Windows NT)'
values = {'name' : 'Michael Foord',
          'location' : 'Northampton',
          'language' : 'Python' }
headers = { 'User-Agent' : user_agent }

data = urllib.urlencode(values)
req = urllib2.Request(url, data, headers)
response = urllib2.urlopen(req)
the_page = response.read()
```

The response also has two useful methods. See the section on [info and geturl](#) which comes after we have a look at what happens when things go wrong.

## 3 Handling Exceptions

`urlopen` raises `URLError` when it cannot handle a response (though as usual with Python APIs, built-in exceptions such as `ValueError`, `TypeError` etc. may also be raised).

`HTTPError` is the subclass of `URLError` raised in the specific case of HTTP URLs.

### 3.1 URLError

Often, `URLError` is raised because there is no network connection (no route to the specified server), or the specified server doesn't exist. In this case, the exception raised will have a `'reason'` attribute, which is a tuple containing an error code and a text error message.

e.g.

```
>>> req = urllib2.Request('http://www.pretend_server.org')
>>> try: urllib2.urlopen(req)
>>> except URLError, e:
>>>     print e.reason
```

---

<sup>2</sup> Like Google for example. The *proper* way to use google from a program is to use `PyGoogle` of course. See [Voidspace Google](#) for some examples of using the Google API.

<sup>3</sup> Browser sniffing is a very bad practise for website design - building sites using web standards is much more sensible. Unfortunately a lot of sites still send different versions to different browsers.

<sup>4</sup> The user agent for MSIE 6 is `'Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1; .NET CLR 1.1.4322)'`

<sup>5</sup> For details of more HTTP request headers, see [Quick Reference to HTTP Headers](#).

```
>>>
(4, 'getaddrinfo failed')
```

## 3.2 HTTPError

Every HTTP response from the server contains a numeric “status code”. Sometimes the status code indicates that the server is unable to fulfil the request. The default handlers will handle some of these responses for you (for example, if the response is a “redirection” that requests the client fetch the document from a different URL, `urllib2` will handle that for you). For those it can’t handle, `urlopen` will raise an `HTTPError`. Typical errors include ‘404’ (page not found), ‘403’ (request forbidden), and ‘401’ (authentication required).

See section 10 of RFC 2616 for a reference on all the HTTP error codes.

The `HTTPError` instance raised will have an integer ‘code’ attribute, which corresponds to the error sent by the server.

### Error Codes

Because the default handlers handle redirects (codes in the 300 range), and codes in the 100-299 range indicate success, you will usually only see error codes in the 400-599 range.

`BaseHTTPServer.BaseHTTPRequestHandler.responses` is a useful dictionary of response codes in that shows all the response codes used by RFC 2616. The dictionary is reproduced here for convenience

```
# Table mapping response codes to messages; entries have the
# form {code: (shortmessage, longmessage)}.
responses = {
    100: ('Continue', 'Request received, please continue'),
    101: ('Switching Protocols',
         'Switching to new protocol; obey Upgrade header'),

    200: ('OK', 'Request fulfilled, document follows'),
    201: ('Created', 'Document created, URL follows'),
    202: ('Accepted',
         'Request accepted, processing continues off-line'),
    203: ('Non-Authoritative Information', 'Request fulfilled from cache'),
    204: ('No Content', 'Request fulfilled, nothing follows'),
    205: ('Reset Content', 'Clear input form for further input.'),
    206: ('Partial Content', 'Partial content follows.'),

    300: ('Multiple Choices',
         'Object has several resources -- see URI list'),
    301: ('Moved Permanently', 'Object moved permanently -- see URI list'),
    302: ('Found', 'Object moved temporarily -- see URI list'),
    303: ('See Other', 'Object moved -- see Method and URL list'),
    304: ('Not Modified',
         'Document has not changed since given time'),
    305: ('Use Proxy',
         'You must use proxy specified in Location to access this '
         'resource.'),
    307: ('Temporary Redirect',
         'Object moved temporarily -- see URI list'),

    400: ('Bad Request',
```

```

    'Bad request syntax or unsupported method'),
401: ('Unauthorized',
    'No permission -- see authorization schemes'),
402: ('Payment Required',
    'No payment -- see charging schemes'),
403: ('Forbidden',
    'Request forbidden -- authorization will not help'),
404: ('Not Found', 'Nothing matches the given URI'),
405: ('Method Not Allowed',
    'Specified method is invalid for this server.'),
406: ('Not Acceptable', 'URI not available in preferred format.'),
407: ('Proxy Authentication Required', 'You must authenticate with '
    'this proxy before proceeding.'),
408: ('Request Timeout', 'Request timed out; try again later.'),
409: ('Conflict', 'Request conflict.'),
410: ('Gone',
    'URI no longer exists and has been permanently removed.'),
411: ('Length Required', 'Client must specify Content-Length.'),
412: ('Precondition Failed', 'Precondition in headers is false.'),
413: ('Request Entity Too Large', 'Entity is too large.'),
414: ('Request-URI Too Long', 'URI is too long.'),
415: ('Unsupported Media Type', 'Entity body in unsupported format.'),
416: ('Requested Range Not Satisfiable',
    'Cannot satisfy request range.'),
417: ('Expectation Failed',
    'Expect condition could not be satisfied.'),

500: ('Internal Server Error', 'Server got itself in trouble'),
501: ('Not Implemented',
    'Server does not support this operation'),
502: ('Bad Gateway', 'Invalid responses from another server/proxy.'),
503: ('Service Unavailable',
    'The server cannot process the request due to a high load'),
504: ('Gateway Timeout',
    'The gateway server did not receive a timely response'),
505: ('HTTP Version Not Supported', 'Cannot fulfill request.'),
}

```

When an error is raised the server responds by returning an HTTP error code *and* an error page. You can use the `HTTPError` instance as a response on the page returned. This means that as well as the code attribute, it also has `read`, `geturl`, and `info`, methods.

```

>>> req = urllib2.Request('http://www.python.org/fish.html')
>>> try:
>>>     urllib2.urlopen(req)
>>> except HTTPError, e:
>>>     print e.code
>>>     print e.read()
>>>
404
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
    "http://www.w3.org/TR/html4/loose.dtd">
<?xml-stylesheet href="./css/ht2html.css"
    type="text/css"?>
<html><head><title>Error 404: File Not Found</title>

```

..... etc...

### 3.3 Wrapping it Up

So if you want to be prepared for `HTTPError` or `URLError` there are two basic approaches. I prefer the second approach.

#### Number 1

```
from urllib2 import Request, urlopen, URLError, HTTPError
req = Request(someurl)
try:
    response = urlopen(req)
except HTTPError, e:
    print 'The server couldn\'t fulfill the request.'
    print 'Error code: ', e.code
except URLError, e:
    print 'We failed to reach a server.'
    print 'Reason: ', e.reason
else:
    # everything is fine
```

---

**Note:** The `except HTTPError` *must* come first, otherwise `except URLError` will *also* catch an `HTTPError`.

---

#### Number 2

```
from urllib2 import Request, urlopen, URLError
req = Request(someurl)
try:
    response = urlopen(req)
except URLError, e:
    if hasattr(e, 'reason'):
        print 'We failed to reach a server.'
        print 'Reason: ', e.reason
    elif hasattr(e, 'code'):
        print 'The server couldn\'t fulfill the request.'
        print 'Error code: ', e.code
else:
    # everything is fine
```

## 4 info and geturl

The response returned by `urlopen` (or the `HTTPError` instance) has two useful methods `info()` and `geturl()`.

**geturl** - this returns the real URL of the page fetched. This is useful because `urlopen` (or the opener object used) may have followed a redirect. The URL of the page fetched may not be the same as the URL requested.

**info** - this returns a dictionary-like object that describes the page fetched, particularly the headers sent by the server. It is currently an `httplib.HTTPMessage` instance.

Typical headers include ‘Content-length’, ‘Content-type’, and so on. See the [Quick Reference to HTTP Headers](#) for a useful listing of HTTP headers with brief explanations of their meaning and use.

## 5 Openers and Handlers

When you fetch a URL you use an opener (an instance of the perhaps confusingly-named `urllib2.OpenerDirector`). Normally we have been using the default opener - via `urlopen` - but you can create custom openers. Openers use handlers. All the “heavy lifting” is done by the handlers. Each handler knows how to open URLs for a particular URL scheme (`http`, `ftp`, etc.), or how to handle an aspect of URL opening, for example HTTP redirections or HTTP cookies.

You will want to create openers if you want to fetch URLs with specific handlers installed, for example to get an opener that handles cookies, or to get an opener that does not handle redirections.

To create an opener, instantiate an `OpenerDirector`, and then call `.add_handler(some_handler_instance)` repeatedly.

Alternatively, you can use `build_opener`, which is a convenience function for creating opener objects with a single function call. `build_opener` adds several handlers by default, but provides a quick way to add more and/or override the default handlers.

Other sorts of handlers you might want to can handle proxies, authentication, and other common but slightly specialised situations.

`install_opener` can be used to make an opener object the (global) default opener. This means that calls to `urlopen` will use the opener you have installed.

Opener objects have an `open` method, which can be called directly to fetch urls in the same way as the `urlopen` function: there’s no need to call `install_opener`, except as a convenience.

## 6 Basic Authentication

To illustrate creating and installing a handler we will use the `HTTPBasicAuthHandler`. For a more detailed discussion of this subject – including an explanation of how Basic Authentication works - see the [Basic Authentication Tutorial](#).

When authentication is required, the server sends a header (as well as the 401 error code) requesting authentication. This specifies the authentication scheme and a ‘realm’. The header looks like: `WWW-Authenticate: SCHEME realm="REALM"`.

e.g.

```
WWW-Authenticate: Basic realm="cPanel Users"
```

The client should then retry the request with the appropriate name and password for the realm included as a header in the request. This is ‘basic authentication’. In order to simplify this process we can create an instance of `HTTPBasicAuthHandler` and an opener to use this handler.

The `HTTPBasicAuthHandler` uses an object called a password manager to handle the mapping of URLs and realms to passwords and usernames. If you know what the realm is (from the authentication header sent by the server), then you can use a `HTTPPasswordMgr`. Frequently one doesn’t care what the realm is. In that case, it is convenient to use `HTTPPasswordMgrWithDefaultRealm`. This allows you to specify a default username and password for a URL. This will be supplied in the absence of you providing an alternative combination for a specific realm. We indicate this by providing `None` as the realm argument to the `add_password` method.

The top-level URL is the first URL that requires authentication. URLs “deeper” than the URL you pass to `.add_password()` will also match.

```

# create a password manager
password_mgr = urllib2.HTTPPasswordMgrWithDefaultRealm()

# Add the username and password.
# If we knew the realm, we could use it instead of None.
top_level_url = "http://example.com/foo/"
password_mgr.add_password(None, top_level_url, username, password)

handler = urllib2.HTTPBasicAuthHandler(password_mgr)

# create "opener" (OpenerDirector instance)
opener = urllib2.build_opener(handler)

# use the opener to fetch a URL
opener.open(a_url)

# Install the opener.
# Now all calls to urllib2.urlopen use our opener.
urllib2.install_opener(opener)

```

---

**Note:** In the above example we only supplied our `HTTPBasicAuthHandler` to `build_opener`. By default openers have the handlers for normal situations – `ProxyHandler`, `UnknownHandler`, `HTTPHandler`, `HTTPDefaultErrorHandler`, `HTTPRedirectHandler`, `FTPHandler`, `FileHandler`, `HTTPErrorProcessor`.

---

`top_level_url` is in fact *either* a full URL (including the ‘http:’ scheme component and the hostname and optionally the port number) e.g. “`http://example.com/`” or an “authority” (i.e. the hostname, optionally including the port number) e.g. “`example.com`” or “`example.com:8080`” (the latter example includes a port number). The authority, if present, must NOT contain the “userinfo” component - for example “`joe@password:example.com`” is not correct.

## 7 Proxies

`urllib2` will auto-detect your proxy settings and use those. This is through the `ProxyHandler` which is part of the normal handler chain. Normally that’s a good thing, but there are occasions when it may not be helpful<sup>6</sup>. One way to do this is to setup our own `ProxyHandler`, with no proxies defined. This is done using similar steps to setting up a [Basic Authentication handler](#) :

```

>>> proxy_support = urllib2.ProxyHandler({})
>>> opener = urllib2.build_opener(proxy_support)
>>> urllib2.install_opener(opener)

```

---

**Note:** Currently `urllib2` *does not* support fetching of `https` locations through a proxy. However, this can be enabled by extending `urllib2` as shown in the recipe<sup>7</sup>.

---

<sup>6</sup> In my case I have to use a proxy to access the internet at work. If you attempt to fetch *localhost* URLs through this proxy it blocks them. IE is set to use the proxy, which `urllib2` picks up on. In order to test scripts with a localhost server, I have to prevent `urllib2` from using the proxy.

<sup>7</sup> `urllib2` opener for SSL proxy (CONNECT method): [ASPN Cookbook Recipe](#).

## 8 Sockets and Layers

The Python support for fetching resources from the web is layered. urllib2 uses the httplib library, which in turn uses the socket library.

As of Python 2.3 you can specify how long a socket should wait for a response before timing out. This can be useful in applications which have to fetch web pages. By default the socket module has *no timeout* and can hang. Currently, the socket timeout is not exposed at the httplib or urllib2 levels. However, you can set the default timeout globally for all sockets using

```
import socket
import urllib2

# timeout in seconds
timeout = 10
socket.setdefaulttimeout(timeout)

# this call to urllib2.urlopen now uses the default timeout
# we have set in the socket module
req = urllib2.Request('http://www.voidspace.org.uk')
response = urllib2.urlopen(req)
```

---

## 9 Footnotes

This document was reviewed and revised by John Lee.

## Index

### R

#### RFC

RFC 2616, ii

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# HOWTO Use Python in the web

*Release 2.7.3*

**Guido van Rossum**  
**Fred L. Drake, Jr., editor**

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**Python Software Foundation**  
Email: docs@python.org

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**Author** Marek Kubica

## Abstract

This document shows how Python fits into the web. It presents some ways to integrate Python with a web server, and general practices useful for developing web sites.

Programming for the Web has become a hot topic since the rise of “Web 2.0”, which focuses on user-generated content on web sites. It has always been possible to use Python for creating web sites, but it was a rather tedious task. Therefore, many frameworks and helper tools have been created to assist developers in creating faster and more robust sites. This HOWTO describes some of the methods used to combine Python with a web server to create dynamic content. It is not meant as a complete introduction, as this topic is far too broad to be covered in one single document. However, a short overview of the most popular libraries is provided.

### See Also:

While this HOWTO tries to give an overview of Python in the web, it cannot always be as up to date as desired. Web development in Python is rapidly moving forward, so the wiki page on [Web Programming](#) may be more in sync with recent development.

## 1 The Low-Level View

When a user enters a web site, their browser makes a connection to the site’s web server (this is called the *request*). The server looks up the file in the file system and sends it back to the user’s browser, which displays it (this is the *response*). This is roughly how the underlying protocol, HTTP, works.

Dynamic web sites are not based on files in the file system, but rather on programs which are run by the web server when a request comes in, and which *generate* the content that is returned to the user. They can do all sorts of useful things, like display the postings of a bulletin board, show your email, configure software, or just display the current time. These programs can be written in any programming language the server supports. Since most servers support Python, it is easy to use Python to create dynamic web sites.

Most HTTP servers are written in C or C++, so they cannot execute Python code directly – a bridge is needed between the server and the program. These bridges, or rather interfaces, define how programs interact with the server. There have been numerous attempts to create the best possible interface, but there are only a few worth mentioning.

Not every web server supports every interface. Many web servers only support old, now-obsolete interfaces; however, they can often be extended using third-party modules to support newer ones.

### 1.1 Common Gateway Interface

This interface, most commonly referred to as “CGI”, is the oldest, and is supported by nearly every web server out of the box. Programs using CGI to communicate with their web server need to be started by the server for every request. So, every request starts a new Python interpreter – which takes some time to start up – thus making the whole interface only usable for low load situations.

The upside of CGI is that it is simple – writing a Python program which uses CGI is a matter of about three lines of code. This simplicity comes at a price: it does very few things to help the developer.

Writing CGI programs, while still possible, is no longer recommended. With *WSGI*, a topic covered later in this document, it is possible to write programs that emulate CGI, so they can be run as CGI if no better option is available.

### See Also:

The Python standard library includes some modules that are helpful for creating plain CGI programs:

- `cgi` – Handling of user input in CGI scripts

- `cgitb` – Displays nice tracebacks when errors happen in CGI applications, instead of presenting a “500 Internal Server Error” message

The Python wiki features a page on [CGI scripts](#) with some additional information about CGI in Python.

## Simple script for testing CGI

To test whether your web server works with CGI, you can use this short and simple CGI program:

```
#!/usr/bin/env python
# -*- coding: UTF-8 -*-

# enable debugging
import cgitb
cgitb.enable()

print "Content-Type: text/plain;charset=utf-8"
print

print "Hello World!"
```

Depending on your web server configuration, you may need to save this code with a `.py` or `.cgi` extension. Additionally, this file may also need to be in a `cgi-bin` folder, for security reasons.

You might wonder what the `cgitb` line is about. This line makes it possible to display a nice traceback instead of just crashing and displaying an “Internal Server Error” in the user’s browser. This is useful for debugging, but it might risk exposing some confidential data to the user. You should not use `cgitb` in production code for this reason. You should *always* catch exceptions, and display proper error pages – end-users don’t like to see nondescript “Internal Server Errors” in their browsers.

## Setting up CGI on your own server

If you don’t have your own web server, this does not apply to you. You can check whether it works as-is, and if not you will need to talk to the administrator of your web server. If it is a big host, you can try filing a ticket asking for Python support.

If you are your own administrator or want to set up CGI for testing purposes on your own computers, you have to configure it by yourself. There is no single way to configure CGI, as there are many web servers with different configuration options. Currently the most widely used free web server is [Apache HTTPd](#), or Apache for short. Apache can be easily installed on nearly every system using the system’s package management tool. [lighttpd](#) is another alternative and is said to have better performance. On many systems this server can also be installed using the package management tool, so manually compiling the web server may not be needed.

- On Apache you can take a look at the [Dynamic Content with CGI](#) tutorial, where everything is described. Most of the time it is enough just to set `+ExecCGI`. The tutorial also describes the most common gotchas that might arise.
- On [lighttpd](#) you need to use the [CGI module](#), which can be configured in a straightforward way. It boils down to setting `cgi.assign` properly.

## Common problems with CGI scripts

Using CGI sometimes leads to small annoyances while trying to get these scripts to run. Sometimes a seemingly correct script does not work as expected, the cause being some small hidden problem that’s difficult to spot.

Some of these potential problems are:

- The Python script is not marked as executable. When CGI scripts are not executable most web servers will let the user download it, instead of running it and sending the output to the user. For CGI scripts to run properly on Unix-like operating systems, the `+x` bit needs to be set. Using `chmod a+x your_script.py` may solve this problem.
- On a Unix-like system, The line endings in the program file must be Unix style line endings. This is important because the web server checks the first line of the script (called shebang) and tries to run the program specified there. It gets easily confused by Windows line endings (Carriage Return & Line Feed, also called CRLF), so you have to convert the file to Unix line endings (only Line Feed, LF). This can be done automatically by uploading the file via FTP in text mode instead of binary mode, but the preferred way is just telling your editor to save the files with Unix line endings. Most editors support this.
- Your web server must be able to read the file, and you need to make sure the permissions are correct. On unix-like systems, the server often runs as user and group `www-data`, so it might be worth a try to change the file ownership, or making the file world readable by using `chmod a+r your_script.py`.
- The web server must know that the file you're trying to access is a CGI script. Check the configuration of your web server, as it may be configured to expect a specific file extension for CGI scripts.
- On Unix-like systems, the path to the interpreter in the shebang (`#!/usr/bin/env python`) must be correct. This line calls `/usr/bin/env` to find Python, but it will fail if there is no `/usr/bin/env`, or if Python is not in the web server's path. If you know where your Python is installed, you can also use that full path. The commands `whereis python` and `type -p python` could help you find where it is installed. Once you know the path, you can change the shebang accordingly: `#!/usr/bin/python`.
- The file must not contain a BOM (Byte Order Mark). The BOM is meant for determining the byte order of UTF-16 and UTF-32 encodings, but some editors write this also into UTF-8 files. The BOM interferes with the shebang line, so be sure to tell your editor not to write the BOM.
- If the web server is using `mod_python`, `mod_python` may be having problems. `mod_python` is able to handle CGI scripts by itself, but it can also be a source of issues.

## 1.2 mod\_python

People coming from PHP often find it hard to grasp how to use Python in the web. Their first thought is mostly `mod_python`, because they think that this is the equivalent to `mod_php`. Actually, there are many differences. What `mod_python` does is embed the interpreter into the Apache process, thus speeding up requests by not having to start a Python interpreter for each request. On the other hand, it is not “Python intermixed with HTML” in the way that PHP is often intermixed with HTML. The Python equivalent of that is a template engine. `mod_python` itself is much more powerful and provides more access to Apache internals. It can emulate CGI, work in a “Python Server Pages” mode (similar to JSP) which is “HTML intermingled with Python”, and it has a “Publisher” which designates one file to accept all requests and decide what to do with them.

`mod_python` does have some problems. Unlike the PHP interpreter, the Python interpreter uses caching when executing files, so changes to a file will require the web server to be restarted. Another problem is the basic concept – Apache starts child processes to handle the requests, and unfortunately every child process needs to load the whole Python interpreter even if it does not use it. This makes the whole web server slower. Another problem is that, because `mod_python` is linked against a specific version of `libpython`, it is not possible to switch from an older version to a newer (e.g. 2.4 to 2.5) without recompiling `mod_python`. `mod_python` is also bound to the Apache web server, so programs written for `mod_python` cannot easily run on other web servers.

These are the reasons why `mod_python` should be avoided when writing new programs. In some circumstances it still might be a good idea to use `mod_python` for deployment, but WSGI makes it possible to run WSGI programs under `mod_python` as well.

## 1.3 FastCGI and SCGI

FastCGI and SCGI try to solve the performance problem of CGI in another way. Instead of embedding the interpreter into the web server, they create long-running background processes. There is still a module in the web server which makes it possible for the web server to “speak” with the background process. As the background process is independent of the server, it can be written in any language, including Python. The language just needs to have a library which handles the communication with the webserver.

The difference between FastCGI and SCGI is very small, as SCGI is essentially just a “simpler FastCGI”. As the web server support for SCGI is limited, most people use FastCGI instead, which works the same way. Almost everything that applies to SCGI also applies to FastCGI as well, so we’ll only cover the latter.

These days, FastCGI is never used directly. Just like `mod_python`, it is only used for the deployment of WSGI applications.

### See Also:

- [FastCGI, SCGI, and Apache: Background and Future](#) is a discussion on why the concept of FastCGI and SCGI is better than that of `mod_python`.

## Setting up FastCGI

Each web server requires a specific module.

- Apache has both `mod_fastcgi` and `mod_fcgid`. `mod_fastcgi` is the original one, but it has some licensing issues, which is why it is sometimes considered non-free. `mod_fcgid` is a smaller, compatible alternative. One of these modules needs to be loaded by Apache.
- `lighttpd` ships its own FastCGI module as well as an SCGI module.
- `nginx` also supports FastCGI.

Once you have installed and configured the module, you can test it with the following WSGI-application:

```
#!/usr/bin/env python
# -*- coding: UTF-8 -*-

from cgi import escape
import sys, os
from flup.server.fcgi import WSGIServer

def app(environ, start_response):
    start_response('200 OK', [('Content-Type', 'text/html')])

    yield '<h1>FastCGI Environment</h1>'
    yield '<table>'
    for k, v in sorted(environ.items()):
        yield '<tr><th>%s</th><td>%s</td></tr>' % (escape(k), escape(v))
    yield '</table>'

WSGIServer(app).run()
```

This is a simple WSGI application, but you need to install `flup` first, as `flup` handles the low level FastCGI access.

### See Also:

There is some documentation on [setting up Django with FastCGI](#), most of which can be reused for other WSGI-compliant frameworks and libraries. Only the `manage.py` part has to be changed, the example used here can be used instead. Django does more or less the exact same thing.

## 1.4 mod\_wsgi

`mod_wsgi` is an attempt to get rid of the low level gateways. Given that FastCGI, SCGI, and `mod_python` are mostly used to deploy WSGI applications, `mod_wsgi` was started to directly embed WSGI applications into the Apache web server. `mod_wsgi` is specifically designed to host WSGI applications. It makes the deployment of WSGI applications much easier than deployment using other low level methods, which need glue code. The downside is that `mod_wsgi` is limited to the Apache web server; other servers would need their own implementations of `mod_wsgi`.

`mod_wsgi` supports two modes: embedded mode, in which it integrates with the Apache process, and daemon mode, which is more FastCGI-like. Unlike FastCGI, `mod_wsgi` handles the worker-processes by itself, which makes administration easier.

## 2 Step back: WSGI

WSGI has already been mentioned several times, so it has to be something important. In fact it really is, and now it is time to explain it.

The *Web Server Gateway Interface*, or WSGI for short, is defined in

**PEP 333** and is currently the best way to do Python web programming. While it is great for programmers writing frameworks, a normal web developer does not need to get in direct contact with it. When choosing a framework for web development it is a good idea to choose one which supports WSGI.

The big benefit of WSGI is the unification of the application programming interface. When your program is compatible with WSGI – which at the outer level means that the framework you are using has support for WSGI – your program can be deployed via any web server interface for which there are WSGI wrappers. You do not need to care about whether the application user uses `mod_python` or FastCGI or `mod_wsgi` – with WSGI your application will work on any gateway interface. The Python standard library contains its own WSGI server, `wsgiref`, which is a small web server that can be used for testing.

A really great WSGI feature is middleware. Middleware is a layer around your program which can add various functionality to it. There is quite a bit of [middleware](#) already available. For example, instead of writing your own session management (HTTP is a stateless protocol, so to associate multiple HTTP requests with a single user your application must create and manage such state via a session), you can just download middleware which does that, plug it in, and get on with coding the unique parts of your application. The same thing with compression – there is existing middleware which handles compressing your HTML using gzip to save on your server's bandwidth. Authentication is another a problem easily solved using existing middleware.

Although WSGI may seem complex, the initial phase of learning can be very rewarding because WSGI and the associated middleware already have solutions to many problems that might arise while developing web sites.

### 2.1 WSGI Servers

The code that is used to connect to various low level gateways like CGI or `mod_python` is called a *WSGI server*. One of these servers is `flup`, which supports FastCGI and SCGI, as well as [AJP](#). Some of these servers are written in Python, as `flup` is, but there also exist others which are written in C and can be used as drop-in replacements.

There are many servers already available, so a Python web application can be deployed nearly anywhere. This is one big advantage that Python has compared with other web technologies.

#### See Also:

A good overview of WSGI-related code can be found in the [WSGI homepage](#), which contains an extensive list of [WSGI servers](#) which can be used by *any* application supporting WSGI.

You might be interested in some WSGI-supporting modules already contained in the standard library, namely:

- `wsgiref` – some tiny utilities and servers for WSGI

## 2.2 Case study: MoinMoin

What does WSGI give the web application developer? Let's take a look at an application that's been around for a while, which was written in Python without using WSGI.

One of the most widely used wiki software packages is [MoinMoin](#). It was created in 2000, so it predates WSGI by about three years. Older versions needed separate code to run on CGI, `mod_python`, FastCGI and standalone.

It now includes support for WSGI. Using WSGI, it is possible to deploy MoinMoin on any WSGI compliant server, with no additional glue code. Unlike the pre-WSGI versions, this could include WSGI servers that the authors of MoinMoin know nothing about.

## 3 Model-View-Controller

The term *MVC* is often encountered in statements such as “framework *foo* supports MVC”. MVC is more about the overall organization of code, rather than any particular API. Many web frameworks use this model to help the developer bring structure to their program. Bigger web applications can have lots of code, so it is a good idea to have an effective structure right from the beginning. That way, even users of other frameworks (or even other languages, since MVC is not Python-specific) can easily understand the code, given that they are already familiar with the MVC structure.

MVC stands for three components:

- The *model*. This is the data that will be displayed and modified. In Python frameworks, this component is often represented by the classes used by an object-relational mapper.
- The *view*. This component's job is to display the data of the model to the user. Typically this component is implemented via templates.
- The *controller*. This is the layer between the user and the model. The controller reacts to user actions (like opening some specific URL), tells the model to modify the data if necessary, and tells the view code what to display,

While one might think that MVC is a complex design pattern, in fact it is not. It is used in Python because it has turned out to be useful for creating clean, maintainable web sites.

---

**Note:** While not all Python frameworks explicitly support MVC, it is often trivial to create a web site which uses the MVC pattern by separating the data logic (the model) from the user interaction logic (the controller) and the templates (the view). That's why it is important not to write unnecessary Python code in the templates – it works against the MVC model and creates chaos in the code base, making it harder to understand and modify.

---

### See Also:

The English Wikipedia has an article about the [Model-View-Controller pattern](#). It includes a long list of web frameworks for various programming languages.

## 4 Ingredients for Websites

Websites are complex constructs, so tools have been created to help web developers make their code easier to write and more maintainable. Tools like these exist for all web frameworks in all languages. Developers are not forced to

use these tools, and often there is no “best” tool. It is worth learning about the available tools because they can greatly simplify the process of developing a web site.

#### See Also:

There are far more components than can be presented here. The Python wiki has a page about these components, called [Web Components](#).

## 4.1 Templates

Mixing of HTML and Python code is made possible by a few libraries. While convenient at first, it leads to horribly unmaintainable code. That’s why templates exist. Templates are, in the simplest case, just HTML files with placeholders. The HTML is sent to the user’s browser after filling in the placeholders.

Python already includes two ways to build simple templates:

```
>>> template = "<html><body><h1>Hello %s!</h1></body></html>"
>>> print template % "Reader"
<html><body><h1>Hello Reader!</h1></body></html>
```

```
>>> from string import Template
>>> template = Template("<html><body><h1>Hello ${name}</h1></body></html>")
>>> print template.substitute(dict(name='Dinsdale'))
<html><body><h1>Hello Dinsdale!</h1></body></html>
```

To generate complex HTML based on non-trivial model data, conditional and looping constructs like Python’s *for* and *if* are generally needed. *Template engines* support templates of this complexity.

There are a lot of template engines available for Python which can be used with or without a [framework](#). Some of these define a plain-text programming language which is easy to learn, partly because it is limited in scope. Others use XML, and the template output is guaranteed to be always be valid XML. There are many other variations.

Some [frameworks](#) ship their own template engine or recommend one in particular. In the absence of a reason to use a different template engine, using the one provided by or recommended by the framework is a good idea.

Popular template engines include:

- [Mako](#)
- [Genshi](#)
- [Jinja](#)

#### See Also:

There are many template engines competing for attention, because it is pretty easy to create them in Python. The page [Templating](#) in the wiki lists a big, ever-growing number of these. The three listed above are considered “second generation” template engines and are a good place to start.

## 4.2 Data persistence

*Data persistence*, while sounding very complicated, is just about storing data. This data might be the text of blog entries, the postings on a bulletin board or the text of a wiki page. There are, of course, a number of different ways to store information on a web server.

Often, relational database engines like [MySQL](#) or [PostgreSQL](#) are used because of their good performance when handling very large databases consisting of millions of entries. There is also a small database engine called [SQLite](#), which is bundled with Python in the `sqlite3` module, and which uses only one file. It has no other dependencies. For smaller sites SQLite is just enough.

Relational databases are *queried* using a language called [SQL](#). Python programmers in general do not like SQL too much, as they prefer to work with objects. It is possible to save Python objects into a database using a technology called [ORM](#) (Object Relational Mapping). ORM translates all object-oriented access into SQL code under the hood, so the developer does not need to think about it. Most [frameworks](#) use ORMs, and it works quite well.

A second possibility is storing data in normal, plain text files (some times called “flat files”). This is very easy for simple sites, but can be difficult to get right if the web site is performing many updates to the stored data.

A third possibility are object oriented databases (also called “object databases”). These databases store the object data in a form that closely parallels the way the objects are structured in memory during program execution. (By contrast, ORMs store the object data as rows of data in tables and relations between those rows.) Storing the objects directly has the advantage that nearly all objects can be saved in a straightforward way, unlike in relational databases where some objects are very hard to represent.

[Frameworks](#) often give hints on which data storage method to choose. It is usually a good idea to stick to the data store recommended by the framework unless the application has special requirements better satisfied by an alternate storage mechanism.

**See Also:**

- [Persistence Tools](#) lists possibilities on how to save data in the file system. Some of these modules are part of the standard library
- [Database Programming](#) helps with choosing a method for saving data
- [SQLAlchemy](#), the most powerful OR-Mapper for Python, and [Elixir](#), which makes SQLAlchemy easier to use
- [SQLObject](#), another popular OR-Mapper
- [ZODB](#) and [Durus](#), two object oriented databases

## 5 Frameworks

The process of creating code to run web sites involves writing code to provide various services. The code to provide a particular service often works the same way regardless of the complexity or purpose of the web site in question. Abstracting these common solutions into reusable code produces what are called “frameworks” for web development. Perhaps the most well-known framework for web development is Ruby on Rails, but Python has its own frameworks. Some of these were partly inspired by Rails, or borrowed ideas from Rails, but many existed a long time before Rails.

Originally Python web frameworks tended to incorporate all of the services needed to develop web sites as a giant, integrated set of tools. No two web frameworks were interoperable: a program developed for one could not be deployed on a different one without considerable re-engineering work. This led to the development of “minimalist” web frameworks that provided just the tools to communicate between the Python code and the http protocol, with all other services to be added on top via separate components. Some ad hoc standards were developed that allowed for limited interoperability between frameworks, such as a standard that allowed different template engines to be used interchangeably.

Since the advent of WSGI, the Python web framework world has been evolving toward interoperability based on the WSGI standard. Now many web frameworks, whether “full stack” (providing all the tools one needs to deploy the most complex web sites) or minimalist, or anything in between, are built from collections of reusable components that can be used with more than one framework.

The majority of users will probably want to select a “full stack” framework that has an active community. These frameworks tend to be well documented, and provide the easiest path to producing a fully functional web site in minimal time.

## 5.1 Some notable frameworks

There are an incredible number of frameworks, so they cannot all be covered here. Instead we will briefly touch on some of the most popular.

### Django

Django is a framework consisting of several tightly coupled elements which were written from scratch and work together very well. It includes an ORM which is quite powerful while being simple to use, and has a great online administration interface which makes it possible to edit the data in the database with a browser. The template engine is text-based and is designed to be usable for page designers who cannot write Python. It supports template inheritance and filters (which work like Unix pipes). Django has many handy features bundled, such as creation of RSS feeds or generic views, which make it possible to create web sites almost without writing any Python code.

It has a big, international community, the members of which have created many web sites. There are also a lot of add-on projects which extend Django's normal functionality. This is partly due to Django's well written [online documentation](#) and the [Django book](#).

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**Note:** Although Django is an MVC-style framework, it names the elements differently, which is described in the [Django FAQ](#).

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### TurboGears

Another popular web framework for Python is [TurboGears](#). TurboGears takes the approach of using already existing components and combining them with glue code to create a seamless experience. TurboGears gives the user flexibility in choosing components. For example the ORM and template engine can be changed to use packages different from those used by default.

The documentation can be found in the [TurboGears wiki](#), where links to screencasts can be found. TurboGears has also an active user community which can respond to most related questions. There is also a [TurboGears book](#) published, which is a good starting point.

The newest version of TurboGears, version 2.0, moves even further in direction of WSGI support and a component-based architecture. TurboGears 2 is based on the WSGI stack of another popular component-based web framework, [Pylons](#).

### Zope

The Zope framework is one of the "old original" frameworks. Its current incarnation in Zope2 is a tightly integrated full-stack framework. One of its most interesting feature is its tight integration with a powerful object database called the [ZODB](#) (Zope Object Database). Because of its highly integrated nature, Zope wound up in a somewhat isolated ecosystem: code written for Zope wasn't very usable outside of Zope, and vice-versa. To solve this problem the Zope 3 effort was started. Zope 3 re-engineers Zope as a set of more cleanly isolated components. This effort was started before the advent of the WSGI standard, but there is WSGI support for Zope 3 from the [Repoze](#) project. Zope components have many years of production use behind them, and the Zope 3 project gives access to these components to the wider Python community. There is even a separate framework based on the Zope components: [Grok](#).

Zope is also the infrastructure used by the [Plone](#) content management system, one of the most powerful and popular content management systems available.

## Other notable frameworks

Of course these are not the only frameworks that are available. There are many other frameworks worth mentioning.

Another framework that's already been mentioned is [Pylons](#). Pylons is much like TurboGears, but with an even stronger emphasis on flexibility, which comes at the cost of being more difficult to use. Nearly every component can be exchanged, which makes it necessary to use the documentation of every single component, of which there are many. Pylons builds upon [Paste](#), an extensive set of tools which are handy for WSGI.

And that's still not everything. The most up-to-date information can always be found in the Python wiki.

### **See Also:**

The Python wiki contains an extensive list of [web frameworks](#).

Most frameworks also have their own mailing lists and IRC channels, look out for these on the projects' web sites. There is also a general "Python in the Web" IRC channel on freenode called [#python.web](#).



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