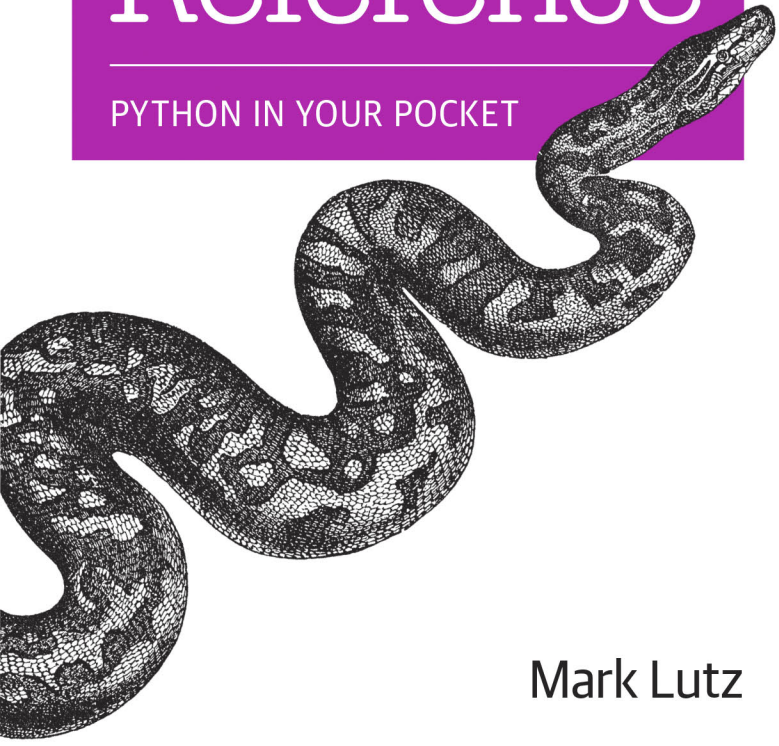
O'REILLY®

5th Edition
Covers Python 3.4 & 2.7

# Python Pocket Reference

PYTHON IN YOUR POCKET



Mark Lutz

O'REILLY®

# Python Pocket Reference

Updated for both Python 3.4 and 2.7, this convenient pocket guide is the perfect on-the-job quick reference. You'll find concise, need-to-know information on Python types and statements, special method names, built-in functions and exceptions, commonly used standard library modules, and other prominent Python tools. The handy index lets you pinpoint exactly what you need.

Written by Mark Lutz—widely recognized as the world's leading Python trainer—*Python Pocket Reference* is an ideal companion to O'Reilly's classic Python tutorials, *Learning Python* and *Programming Python*, also written by Mark.

**This fifth edition covers:**

- Built-in object types, including numbers, lists, dictionaries, and more
- Statements and syntax for creating and processing objects
- Functions and modules for structuring and reusing code
- Python's object-oriented programming tools
- Built-in functions, exceptions, and attributes
- Special operator overloading methods
- Widely used standard library modules and extensions
- Command-line options and development tools
- Python idioms and hints
- The Python SQL Database API

PROGRAMMING LANGUAGES

oreilly.com, Twitter: @oreillymedia

**US $14.99** **CAN $15.99**

ISBN: 978-1-449-35701-6

FIFTH EDITION

# Python Pocket Reference

*Mark Lutz*

Beijing • Cambridge • Farnham • Köln • Sebastopol • Tokyo O'REILLY®

**Python Pocket Reference, Fifth Edition**

by Mark Lutz

Copyright © 2014 Mark Lutz. All rights reserved.

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (*http://my.safaribooksonline.com*). For more information, contact our corporate/institutional sales department: 800-998-9938 or *corporate@oreilly.com*.

**Editor:** Rachel Roumeliotis
**Production Editor:** Kristen Brown
**Copyeditor:** Richard Carey
**Proofreader:** Amanda Kersey
**Indexer:** Lucie Haskins
**Cover Designer:** Randy Comer
**Interior Designer:** David Futato

| | |
|---|---|
| October 1998: | First Edition |
| January 2002: | Second Edition |
| February 2005: | Third Edition |
| October 2009: | Fourth Edition |
| February 2014: | Fifth Edition |

**Revision History for the Fifth Edition:**

2014-01-17: First release

See *http://oreilly.com/catalog/errata.csp?isbn=9781449357016* for release details.

Nutshell Handbook, the Nutshell Handbook logo, and the O'Reilly logo are registered trademarks of O'Reilly Media, Inc. Python Pocket Reference, the image of a rock python, and related trade dress are trademarks of O'Reilly Media, Inc.

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and O'Reilly Media, Inc. was aware of a trademark claim, the designations have been printed in caps or initial caps.

While every precaution has been taken in the preparation of this book, the publisher and authors assume no responsibility for errors or omissions, or for damages resulting from the use of the information contained herein.

ISBN: 978-1-449-35701-6

[M]

# Table of Contents


Introduction 1
Book Conventions 2
Python Command-Line Usage 3
    Python Command Options 4
    Command-Line Program Specification 5
    Python 2.X Command Options 7
Python Environment Variables 7
    Operational Variables 8
    Python Command Option Variables 9
Python Windows Launcher Usage 10
    Launcher File Directives 10
    Launcher Command Lines 11
    Launcher Environment Variables 11
Built-in Types and Operators 12
    Operators and Precedence 12
    Operator Usage Notes 14
    Operations by Category 16
    Sequence Operation Notes 20
Specific Built-in Types 21
    Numbers 22

Strings 24
Unicode Strings 42
Lists 46
Dictionaries 53
Tuples 57
Files 58
Sets 63
Other Types and Conversions 65
Statements and Syntax 67
Syntax Rules 67
Name Rules 69
Specific Statements 71
The Assignment Statement 72
The Expression Statement 76
The print Statement 77
The if Statement 80
The while Statement 80
The for Statement 80
The pass Statement 81
The break Statement 81
The continue Statement 81
The del Statement 81
The def Statement 82
The return Statement 86
The yield Statement 87
The global Statement 88
The nonlocal Statement 89
The import Statement 89
The from Statement 93
The class Statement 95
The try Statement 97
The raise Statement 99

The assert Statement 101
The with Statement 102
Python 2.X Statements 104
Namespace and Scope Rules 105
Qualified Names: Object Namespaces 105
Unqualified Names: Lexical Scopes 105
Nested Scopes and Closures 107
Object-Oriented Programming 108
Classes and Instances 109
Pseudoprivate Attributes 110
New-Style Classes 111
Formal Inheritance Rules 112
Operator Overloading Methods 117
Methods for All Types 118
Methods for Collections (Sequences, Mappings) 123
Methods for Numbers (Binary Operators) 125
Methods for Numbers (Other Operations) 128
Methods for Descriptors 129
Methods for Context Managers 130
Python 2.X Operator Overloading Methods 131
Built-in Functions 134
Python 2.X Built-in Functions 155
Built-in Exceptions 161
Superclasses: Categories 162
Specific Exceptions 163
Specific OSError Exceptions 167
Warning Category Exceptions 169
Warnings Framework 170
Python 3.2 Built-in Exceptions 171
Python 2.X Built-in Exceptions 172
Built-in Attributes 172
Standard Library Modules 173

The sys Module 174
The string Module 182
Functions and Classes 182
Constants 183
The os System Module 184
Administrative Tools 185
Portability Constants 186
Shell Commands 187
Environment Tools 189
File Descriptor Tools 190
File Pathname Tools 193
Process Control 197
The os.path Module 200
The re Pattern-Matching Module 202
Module Functions 202
Regular Expression Objects 205
Match Objects 205
Pattern Syntax 207
Object Persistence Modules 210
The shelve and dbm Modules 211
The pickle Module 213
The tkinter GUI Module and Tools 216
tkinter Example 216
tkinter Core Widgets 217
Common Dialog Calls 218
Additional tkinter Classes and Tools 219
Tcl/Tk-to-Python/tkinter Mappings 220
Internet Modules and Tools 221
Other Standard Library Modules 224
The math Module 224
The time Module 225
The timeit Module 226

The datetime Module 227
The random Module 228
The json Module 228
The subprocess Module 229
The enum Module 229
The struct Module 230
Threading Modules 231
Python SQL Database API 232
API Usage Example 233
Module Interface 234
Connection Objects 234
Cursor Objects 235
Type Objects and Constructors 236
More Hints and Idioms 236
Core Language Hints 237
Environment Hints 238
Usage Hints 240
Assorted Hints 242

**Index** **243**

# Python Pocket Reference

## Introduction

*Python* is a general-purpose, multiparadigm, open source computer programming language, with support for object-oriented, functional, and procedural coding structures. It is commonly used both for standalone programs and for scripting applications in a wide variety of domains, and is generally considered to be one of the most widely used programming languages in the world.

Among Python's features are an emphasis on code readability and library functionality, and a design that optimizes developer productivity, software quality, program portability, and component integration. Python programs run on most platforms in common use, including Unix and Linux, Windows and Macintosh, Java and .NET, Android and iOS, and more.

This *pocket reference* summarizes Python types and statements, special method names, built-in functions and exceptions, commonly used standard library modules, and other prominent Python tools. It is intended to serve as a concise reference tool for developers and is designed to be a companion to other books that provide tutorials, code examples, and other learning materials.

This *fifth edition* covers both Python 3.X and 2.X. It focuses primarily on 3.X, but also documents differences in 2.X along the

way. Specifically, this edition has been updated to be current with Python versions *3.3* and *2.7* as well as prominent enhancements in the imminent *3.4* release, although most of its content also applies both to earlier and to later releases in the 3.X and 2.X lines.

This edition also applies to all major implementations of Python —including CPython, PyPy, Jython, IronPython, and Stackless —and has been updated and expanded for recent changes in language, libraries, and practice. Its changes include new coverage of the MRO and `super()`; formal algorithms of inheritance, imports, context managers, and block indentation; and commonly used library modules and tools, including `json`, `timeit`, `random`, `subprocess`, `enum`, and the new Windows launcher.

# Book Conventions

The following notational conventions are used in this book:

`[]`
: In syntax formats, items in brackets are optional; brackets are also used literally in some parts of Python's syntax as noted where applicable (e.g., lists).

`*`
: In syntax formats, items followed by an asterisk can be repeated zero or more times; star is also used literally in some parts of Python's syntax (e.g., multiplication).

*a* | *b*
: In syntax formats, items separated by a bar are alternatives; bar is also used literally in some parts of Python's syntax (e.g., union).

*Italic*
: Used for filenames and URLs, and to highlight new or important terms.

`Constant width`
: Used for code, commands, and command-line options, and to indicate the names of modules, functions, attributes, variables, and methods.

*Constant width italic*
: Used for replaceable parameter names in the syntax of command lines, expressions, functions, and methods.

`Function()`
: Except where noted, callable functions and methods are denoted by trailing parentheses, to distinguish them from other types of attributes.

See *"Section Header Name"*
: References to other sections in this book are given by section header text in double quotes.

---

**NOTE**

In this book, "3.X" and "2.X" mean that a topic applies to all commonly used releases in a Python line. More specific release numbers are used for topics of more limited scope (e.g., "2.7" means 2.7 only). Because future Python changes can invalidate applicability to future releases, also see Python's "What's New" documents, currently maintained at *http://docs.python.org/3/whatsnew/index.html* for Pythons released after this book.

---

# Python Command-Line Usage

Command lines used to launch Python programs from a system shell have the following format:

```
python [option*]
  [ scriptfile | -c command | -m module | - ] [arg*]
```

In this format, *python* denotes the Python interpreter executable with either a full directory path, or the word `python` that is resolved by the system shell (e.g., via `PATH` settings). Command-line options intended for Python itself appear before the specification of the program code to be run (*option*). Arguments intended for the code to be run appear after the program specification (*arg*).

## Python Command Options

The *option* items in Python command lines are used by Python itself, and can be any of the following in Python 3.X (see "Python 2.X Command Options" ahead for 2.X differences):

`-b`

Issue warnings for calling `str()` with a `bytes` or `bytearray` object and no encoding argument, and comparing a `bytes` or `bytearray` with a `str`. Option `-bb` issues errors instead.

`-B`

Do not write *.pyc* or *.pyo* byte-code files on imports.

`-d`

Turn on parser debugging output (for developers of the Python core).

`-E`

Ignore Python environment variables described ahead (such as `PYTHONPATH`).

`-h`

Print help message and exit.

`-i`

Enter interactive mode after executing a script. Hint: useful for postmortem debugging; see also `pdb.pm()`, described in Python's library manuals.

`-O`

Optimize generated byte code (create and use *.pyo* byte-code files). Currently yields a minor performance improvement.

`-OO`

Operates like `-O`, the previous option, but also removes docstrings from byte code.

`-q`

Do not print version and copyright message on interactive startup (as of Python 3.2).

`-s`
: Do not add the user site directory to the `sys.path` module search path.

`-S`
: Do not imply "import site" on initialization.

`-u`
: Force *stdout* and *stderr* to be unbuffered and binary.

`-v`
: Print a message each time a module is initialized, showing the place from which it is loaded; repeat this flag for more verbose output.

`-V`
: Print Python version number and exit (also available as `--version`).

`-W` *`arg`*
: Warnings control: *`arg`* takes the form *`action`*`:`*`message`*`:` *`category`*`:`*`module`*`:`*`lineno`*. See also "Warning Category Exceptions" ahead, and the `warnings` module documentation in the Python Library Reference manual (available at *http://www.python.org/doc/*).

`-x`
: Skip first line of source, allowing use of non-Unix forms of `#!`*`cmd`*.

`-X` *`option`*
: Set implementation-specific option (as of Python 3.2); see implementation documentation for supported *`option`* values.

## Command-Line Program Specification

Code to be run and command-line arguments to send to it are specified in the following ways in Python command lines:

*scriptfile*
: Denotes the name of a Python script file to run as the main, topmost file of a program (e.g., *python* `main.py` runs the code in `main.py`). The script's name may be an absolute or relative (to ".") filename path, and is made available in `sys.argv[0]`. On some platforms, command lines may also omit the *python* component if they begin with a script file name and have no options for Python itself.

`-c` *command*
: Specifies Python code (as a string) to run (e.g., *python* `-c "print('spam' * 8)"` runs a Python print operation). `sys.argv[0]` is set to `'-c'`.

`-m` *module*
: Runs a module as a script: searches for *module* on `sys.path` and runs it as a top-level file (e.g., *python* `-m pdb s.py` runs the Python debugger module `pdb` located in a standard library directory, with argument `s.py`). *module* may also name a package (e.g., `idlelib.idle`). `sys.argv[0]` is set to the module's full path name.

`–`
: Reads Python commands from the standard input stream, *stdin* (the default); enters interactive mode if *stdin* is a "tty" (interactive device). `sys.argv[0]` is set to `'–'`.

*arg**
: Indicates that anything else on the command line is passed to the script file or command, and appears in the built-in list of strings `sys.argv[1:]`.

If no *scriptfile*, *command*, or *module* is given, Python enters interactive mode, reading commands from *stdin* (and using GNU *readline* for input, if installed), and setting `sys.argv[0]` to `''` (the empty string) unless invoked with option – in the preceding list.

Besides using traditional command lines at a system shell prompt, you can also generally start Python programs by clicking their filenames in a file explorer GUI; by calling functions in the

Python standard library (e.g., `os.popen()`); by using program-launch menu options in IDEs such as IDLE, Komodo, Eclipse, and NetBeans; and so on.

## Python 2.X Command Options

Python 2.X supports the same command-line format, but does not support the `-b` option, which is related to Python 3.X's string type changes, nor the recent `-q` and `-X` additions in 3.X. It supports additional options in 2.6 and 2.7 (some may be present earlier):

`-t` and `-tt`
: Issues warnings for inconsistent mixtures of tabs and spaces in indentation. Option `-tt` issues errors instead. Python 3.X always treats such mixtures as syntax errors (see also "Syntax Rules").

`-Q`
: Division-related options: `-Qold` (the default), `-Qwarn`, `-Qwarnall`, and `-Qnew`. These are subsumed by the new true division behavior of Python 3.X (see also "Operator Usage Notes").

`-3`
: Issues warnings about any Python 3.X incompatibilities in code that the Python standard installation's *2to3* tool cannot trivially fix.

`-R`
: Enables a pseudorandom salt to make hash values of various types be unpredictable between separate invocations of the interpreter, as a defense against denial-of-service attacks. New in Python 2.6.8. This switch is also present in 3.X as of 3.2.3 for compatibility, but this hash randomization is enabled by default as of 3.3.

# Python Environment Variables

Environment (a.k.a. *shell*) variables are systemwide settings that span programs and are used for global configuration.

## Operational Variables

The following are major user-configurable environment variables related to script behavior:

`PYTHONPATH`
: Augments the default search path for imported module files. The format of this variable's value is the same as the shell's `PATH` setting: directory pathnames separated by colons (semicolons on Windows). If set, module imports search for imported files or directories in each directory listed in `PYTHONPATH`, from left to right. Merged into `sys.path`—the full module search path for leftmost components in absolute imports—after the script's directory, and before standard library directories. See also `sys.path` in "The sys Module", and "The import Statement".

`PYTHONSTARTUP`
: If set to the name of a readable file, the Python commands in that file are executed before the first prompt is displayed in interactive mode (useful to define often-used tools).

`PYTHONHOME`
: If set, the value is used as an alternate prefix directory for library modules (or `sys.prefix`, `sys.exec_prefix`). The default module search path uses `sys.prefix/lib`.

`PYTHONCASEOK`
: If set, filename case is ignored in import statements (currently only on Windows and OS X).

`PYTHONIOENCODING`
: Assign to string *`encodingname`*`[:`*`errorhandler`*`]` to override the default Unicode encoding (and optional error handler) used for text transfers made to the *stdin*, *stdout*, and *stderr* streams. This setting may be required for non-ASCII text in some shells (e.g., try setting this to `utf8` or other if prints fail).

`PYTHONHASHSEED`
: If set to "random", a random value is used to seed the hashes of `str`, `bytes`, and `datetime` objects; may also be set to an integer in the range `0...4,294,967,295` to get hash values with a predictable seed (as of Python 3.2.3 and 2.6.8).

`PYTHONFAULTHANDLER`
: If set, Python registers handlers at startup to dump a traceback on fatal signal errors (as of Python 3.3, and equivalent to `-X faulthandler`).

## Python Command Option Variables

The following environment variables are synonymous with some of Python's command-line options (see "Python Command Options"):

`PYTHONDEBUG`
: If nonempty, same as `-d` option.

`PYTHONDONTWRITEBYTECODE`
: If nonempty, same as `-B` option.

`PYTHONINSPECT`
: If nonempty, same as `-i` option.

`PYTHONNOUSERSITE`
: If nonempty, same as `-s` option.

`PYTHONOPTIMIZE`
: If nonempty, same as `-O` option.

`PYTHONUNBUFFERED`
: If nonempty, same as `-u` option.

`PYTHONVERBOSE`
: If nonempty, same as `-v` option.

`PYTHONWARNINGS`
: If nonempty, same as `-W` option, with same value. Also accepts a comma-separated string as equivalent to multiple `-W` options. (As of Python 3.2 and 2.7.)

# Python Windows Launcher Usage

On Windows (only), Python 3.3 and later install a script launcher, also available separately for earlier versions. This launcher consists of the executables `py.exe` (console) and `pyw.exe` (nonconsole), which can be invoked without `PATH` settings; are registered to run Python files via filename associations; and allow Python versions to be selected in three ways—with "`#!`" Unix-like directives at the top of scripts, with command-line arguments, and with configurable defaults.

## Launcher File Directives

The launcher recognizes "`#!`" lines at the top of script files that name Python versions in one of the following forms, in which `*` is either: *empty* to use the default version (currently `2` if installed and similar to omitting a "`#!`" line); a *major* version number (e.g., `3`) to launch the latest version in that line installed; or a *complete* `major.minor` specification, optionally suffixed by `-32` to prefer a 32-bit install (e.g., `3.1-32`):

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

Any Python (`python.exe`) arguments may be given at the end of the line, and Python 3.4 and later may consult `PATH` for "`#!`" lines that give just `python` with no explicit version number.

## Launcher Command Lines

The launcher may also be invoked from a system shell with command lines of the following form:

```
py [pyarg] [pythonarg*] script.py [scriptarg*]
```

More generally, anything that may appear in a `python` command after its *`python`* component may also appear after the optional *`pyarg`* in a `py` command, and is passed on to the spawned Python verbatim. This includes the `-m`, `-c`, and `-` program specification forms; see "Python Command-Line Usage".

The launcher accepts the following argument forms for its optional *`pyarg`*, which mirror the `*` part at the end of a file's "`#!`" line:

```
-2          Launch latest 2.X version installed
-3          Launch latest 3.X version installed
-X.Y        Launch specified version (X is 2 or 3)
-X.Y-32     Launch the specified 32-bit version
```

If both are present, command-line arguments have precedence over values given in "`#!`" lines. As installed, "`#!`" lines may be applied in more contexts (e.g., icon clicks).

## Launcher Environment Variables

The launcher also recognizes optional environment variable settings, which may be used to customize version selection in default or partial cases (e.g., missing or major-only "`#!`" or `py` command argument):

```
PY_PYTHON   Version to use in default cases (else 2)
PY_PYTHON3  Version to use in 3 partials (e.g., 3.2)
PY_PYTHON2  Version to use in 2 partials (e.g., 2.6)
```

These settings are used only by launcher executables, not when *`python`* is invoked directly.

# Built-in Types and Operators

## Operators and Precedence

Table 1 lists Python's expression operators. Operators in the lower cells of this table have higher precedence (i.e., bind tighter) when used in mixed-operator expressions without parentheses.

### Atomic terms and dynamic typing

In Table 1, the replaceable expression items *X*, *Y*, *Z*, *i*, *j*, and *k* may be:

- *Variable names*, replaced with their most recently assigned value
- *Literal expressions*, defined in "Specific Built-in Types"
- *Nested expressions*, taken from any row in this table, possibly in parentheses

Python *variables* follow a *dynamic typing model*—they are not declared, and are created by being assigned; have object references as values, and may reference any type of object; and must be assigned before appearing in expressions, as they have no default value. Case is always significant in variable names (see "Name Rules"). *Objects* referenced by variables are automatically created, and automatically reclaimed when no longer in use by Python's *garbage collector*, which uses reference counters in CPython.

Also in Table 1, replaceable *`attr`* must be the literal (unquoted) name of an attribute; *`args1`* is a formal arguments list as defined in "The def Statement"; *`args2`* is an input arguments list as defined in "The Expression Statement"; and a literal `...` qualifies as an atomic expression in 3.X (only).

The syntax of comprehensions and data structure literals (tuple, list, dictionary, and set) given abstractly in the last three rows of Table 1 is defined in "Specific Built-in Types".

*Table 1. Python 3.X expression operators and precedence*

| Operator | Description |
|---|---|
| `yield` *X* | Generator function result (returns `send()` value) |
| `lambda` *args1*`:` *X* | Anonymous function maker (returns *X* when called) |
| *X* `if` *Y* `else` *Z* | Ternary selection (*X* is evaluated only if *Y* is true) |
| *X* `or` *Y* | Logical OR: *Y* is evaluated only if *X* is false |
| *X* `and` *Y* | Logical AND: *Y* is evaluated only if *X* is true |
| `not` *X* | Logical negation |
| *X* `in` *Y*, *X* `not in` *Y* | Membership: iterables, sets |
| *X* `is` *Y*, *X* `is not` *Y* | Object identity tests |
| *X* `<` *Y*, *X* `<=` *Y*, *X* `>` *Y*, *X* `>=` *Y* | Magnitude comparisons, set subset and superset |
| *X* `==` *Y*, *X* `!=` *Y* | Equality operators |
| *X* `\|` *Y* | Bitwise OR, set union |
| *X* `^` *Y* | Bitwise exclusive OR, set symmetric difference |
| *X* `&` *Y* | Bitwise AND, set intersection |
| *X* `<<` *Y*, *X* `>>` *Y* | Shift *X* left, right by *Y* bits |
| *X* `+` *Y*, *X* `–` *Y* | Addition/concatenation, subtraction/set difference |
| *X* `*` *Y*, *X* `%` *Y*, *X* `/` *Y*, *X* `//` *Y* | Multiplication/repetition, remainder/format, division, floor division |
| `-`*X*, `+`*X* | Unary negation, identity |
| `~`*X* | Bitwise NOT complement (inversion) |
| *X* `**` *Y* | Power (exponentiation) |
| *X*`[`*i*`]` | Indexing (sequence, mapping, others) |
| *X*`[`*i*`:`*j*`:`*k*`]` | Slicing (all three bounds optional) |
| *X*`(`*args2*`)` | Call (function, method, class, other callable) |

| Operator | Description |
|---|---|
| *X*.*attr* | Attribute reference |
| (....) | Tuple, expression, generator expression |
| [....] | List, list comprehension |
| {....} | Dictionary, set, dictionary and set comprehension |

## Operator Usage Notes

- In Python 2.X only, value inequality can be written as either *X* != *Y* or *X* <> *Y*. In Python 3.X, the latter of these options is removed because it is redundant.
- In Python 2.X only, a backquotes expression `*X*` works the same as repr(*X*), and converts objects to display strings. In Python 3.X, use the more readable str() and repr() built-in functions instead.
- In both Python 3.X and 2.X, the *X* // *Y* *floor division* expression always truncates fractional remainders, and returns an integer result for integers.
- The *X* / *Y* expression performs *true division* in 3.X (always retaining remainders in a floating-point result), and *classic division* in 2.X (truncating remainders for integers) unless 3.X's true division is enabled in 2.X with from __future__ import division or Python option -Qnew.
- The syntax [....] is used for both list literals and list comprehension expressions. The latter of these performs an implied loop and collects expression results in a new list.
- The syntax (....) is used for tuples and expressions, as well as generator expressions—a form of list comprehension that produces results on demand, instead of building a result list. Parentheses may sometimes be omitted in all three constructs.

- The syntax `{...}` is used for dictionary literals. In Python 3.X and 2.7, it is also used for set literals, and both dictionary and set comprehensions; use `set()` and looping statements in 2.6 and earlier.
- The `yield` and ternary `if`/`else` selection expressions are available in Python 2.5 and later. The former returns `send()` arguments in generators; the latter is a shorthand for a multiline `if` statement. `yield` requires parentheses if not alone on the right side of an assignment statement.
- Comparison operators may be chained: *X* `<` *Y* `<` *Z* produces the same result as *X* `<` *Y* `and` *Y* `<` *Z*, but *Y* is evaluated only once in the chained form.
- The slice expression *X*`[i:j:k]` is equivalent to indexing with a slice object: *X*`[slice(i, j, k)]`.
- In Python 2.X, magnitude comparisons of mixed types are allowed—converting numbers to a common type, and ordering other mixed types according to the type name. In Python 3.X, nonnumeric mixed-type magnitude comparisons are not allowed and raise exceptions; this includes sorts by proxy.
- Magnitude comparisons for dictionaries are also no longer supported in Python 3.X (although equality tests are); comparing `sorted(`*adict*`.items())` is one possible replacement in 3.X.
- Call expressions allow for positional and keyword arguments, and arbitrarily large numbers of both; see "The Expression Statement" and "The def Statement" for call syntax.
- Python 3.X allows ellipsis (literally, `...`, and known by built-in name `Ellipsis`) to be used as an atomic expression anywhere in source code. This may be used as an alternative to `pass` or `None` in some contexts (e.g., stubbed-out function bodies, type-independent variable initialization).

- Although uncertain at this writing, Python 3.5 or later *may* generalize the `*X` and `**X` star syntax to appear in data structure literals and comprehensions, where it will unpack collections into individual items, much as it currently does in function calls. See "The Assignment Statement" for more details.

## Operations by Category

In this section, trailing parentheses are omitted from `__X__` method names for brevity. In general, all built-in types support the *comparisons* and *Boolean* operations listed in Table 2 (although Python 3.X does not support magnitude comparisons for dictionaries or mixed nonnumeric types).

Boolean *true* means any nonzero number or any nonempty collection object (list, dictionary, etc.), and all objects have a Boolean value. The built-in names `True` and `False` are preassigned to true and false values and behave like integers `1` and `0` with custom display formats. The special object `None` is false and appears in various Python contexts.

Comparisons return `True` or `False` and are automatically applied recursively in compound objects as needed to determine a result.

Boolean `and` and `or` operators stop (short-circuit) as soon as a result is known and return one of the two operand objects—the value on the left or the right of the operator—whose Boolean value gives the result.

*Table 2. Comparisons and Boolean operations*

| Operator | Description |
|---|---|
| `X < Y` | Strictly less than[a] |
| `X <= Y` | Less than or equal to |
| `X > Y` | Strictly greater than |
| `X >= Y` | Greater than or equal to |
| `X == Y` | Equal to (same value) |

| Operator | Description |
|---|---|
| *X* != *Y* | Not equal to (same as *X*<>*Y* in Python 2.X only)[b] |
| *X* is *Y* | Same object |
| *X* is not *Y* | Negated object identity |
| *X* < *Y* < *Z* | Chained comparisons |
| not *X* | If *X* is false then True; else, False |
| *X* or *Y* | If *X* is false then *Y*; else, *X* |
| *X* and *Y* | If *X* is false then *X*; else, *Y* |

[a] To implement comparison expressions, see both the rich comparison (e.g., __lt__ for <) class methods in 3.X and 2.X, and general __cmp__ method in 2.X, described in "Operator Overloading Methods".

[b] != and <> both mean not equal by value in 2.X, but != is the preferred syntax in 2.X and the only supported option in 3.X. is performs an identity test; == performs value comparison, and so is much more generally useful.

Tables 3 through 6 define operations common to types in the three major type categories—*sequence* (positionally ordered), *mapping* (access-by-key), and *number* (all numeric types)—as well as operations available for *mutable* (changeable) types in Python. Most types also export additional type-specific operations (e.g., methods), as described in "Specific Built-in Types".

*Table 3. Sequence operations (strings, lists, tuples, bytes, bytearray)*

| Operation | Description | Class method |
|---|---|---|
| *X* in *S*<br>*X* not in *S* | Membership tests | __contains__,<br>__iter__,<br>__getitem__[a] |
| *S1* + *S2* | Concatenation | __add__ |
| *S* * *N*, *N* * *S* | Repetition | __mul__ |
| *S*[*i*] | Index by offset | __getitem__ |

| Operation | Description | Class method |
|---|---|---|
| `S[i:j]`, `S[i:j:k]` | Slicing: items in *S* from offset *i* through *j*–1 by optional stride *k* | `__getitem__`[b] |
| `len(S)` | Length | `__len__` |
| `min(S)`, `max(S)` | Minimum, maximum item | `__iter__`, `__getitem__` |
| `iter(S)` | Iteration protocol | `__iter__` |
| `for X in S:`, `[expr for X in S]`, `map(func, S)`, etc. | Iteration (all contexts) | `__iter__`, `__getitem__` |

[a] See also "The iteration protocol" for more on these methods and their interplay. If defined, `__contains__` is preferred over `__iter__`, and `__iter__` is preferred over `__getitem__`.

[b] In Python 2.X, you may also define `__getslice__`, `__setslice__`, and `__delslice__` to handle slicing operations. In 3.X, these are removed in favor of passing slice objects to their item-based indexing counterparts. Slice objects may be used explicitly in indexing expressions in place of `i:j:k` bounds.

*Table 4. Mutable sequence operations (lists, bytearray)*

| Operation | Description | Class method |
|---|---|---|
| `S[i] = X` | Index assignment: change item at existing offset *i* to reference *X* | `__setitem__` |
| `S[i:j] = I`, `S[i:j:k] = I` | Slice assignment: *S* from *i* through *j*–1 with optional stride *k* (possibly empty) is replaced by all items in iterable *I* | `__setitem__` |
| `del S[i]` | Index deletion | `__delitem__` |
| `del S[i:j]`, `del S[i:j:k]` | Slice deletion | `__delitem__` |

*Table 5. Mapping operations (dictionaries)*

| Operation | Description | Class method |
|---|---|---|
| `D[k]` | Index by key | `__getitem__` |
| `D[k] = X` | Key assignment: change or create entry for key `k` to reference `X` | `__setitem__` |
| `del D[k]` | Delete item by key | `__delitem__` |
| `len(D)` | Length (number of keys) | `__len__` |
| `k in D` | Key membership test[a] | Same as in Table 3 |
| `k not in D` | Converse of `k in D` | Same as in Table 3 |
| `iter(D)` | Iterator object for `D`'s keys | Same as in Table 3 |
| `for k in D:`, etc. | Iterate through keys in `D` (all iteration contexts) | Same as in Table 3 |

[a] In Python 2.X, key membership may also be coded as `D.has_key(k)`. This method is removed in Python 3.X in favor of the `in` expression, which is also generally preferred in 2.X. See "Dictionaries".

*Table 6. Numeric operations (all number types)*

| Operation | Description | Class method |
|---|---|---|
| `X + Y`, `X - Y` | Add, subtract | `__add__`, `__sub__` |
| `X * Y`, `X / Y`, `X // Y`, `X % Y` | Multiply, divide, floor divide, remainder | `__mul__`, `__truediv__`[a], `__floordiv__`, `__mod__` |
| `-X`, `+X` | Negative, identity | `__neg__`, `__pos__` |
| `X \| Y`, `X & Y`, `X ^ Y` | Bitwise OR, AND, exclusive OR (integers) | `__or__`, `__and__`, `__xor__` |
| `X << N`, `X >> N` | Bitwise left-shift, right-shift (integers) | `__lshift__`, `__rshift__` |
| `~X` | Bitwise invert (integers) | `__invert__` |
| `X ** Y` | `X` to the power `Y` | `__pow__` |
| `abs(X)` | Absolute value | `__abs__` |

| Operation | Description | Class method |
|---|---|---|
| `int(X)` | Convert to integer[b] | `__int__` |
| `float(X)` | Convert to float | `__float__` |
| `complex(X)`, `complex(re,im)` | Make a complex value | `__complex__` |
| `divmod(X, Y)` | Tuple: (`X / Y`, `X % Y`) | `__divmod__` |
| `pow(X, Y[,Z])` | Raise to a power | `__pow__` |

[a] The `/` operator invokes `__truediv__` in Python 3.X, but `__div__` in Python 2.X unless true division is enabled. See "Operator Usage Notes" for division semantics.

[b] In Python 2.X, the `long()` built-in function invokes the `__long__` class method. In Python 3.X, the `int` type subsumes `long`, which is removed.

## Sequence Operation Notes

Examples and notes on selected sequence operations in Table 3 and Table 4:

**Indexing: S[i]**

- Fetches components at offsets (first item is at offset `0`).
- Negative indexes count backward from the end (last item is at offset `-1`).
- *`S`*`[0]` fetches the first item; *`S`*`[1]` fetches the second item.
- *`S`*`[-2]` fetches the second-to-last item (same as *`S`*`[len(`*`S`*`) - 2]`).

**Slicing: S[i:j]**

- Extracts contiguous sections of a sequence, from *`i`* through *`j`*`-1`.
- Slice boundaries *`i`* and *`j`* default to `0` and sequence length `len(`*`S`*`)`.
- *`S`*`[1:3]` fetches from offsets `1` up to, but not including, `3`.
- *`S`*`[1:]` fetches from offsets `1` through the end (`len(`*`S`*`)-1`).

- `S[:-1]` fetches from offsets `0` up to, but not including, the last item.
- `S[:]` makes a top-level (shallow) copy of sequence object *S*.

**Extended slicing: S[i:j:k]**

- The third item *k* is a stride (default `1`), added to the offset of each item extracted.
- `S[::2]` is every other item in entire sequence *S*.
- `S[::-1]` is sequence *S* reversed.
- `S[4:1:-1]` fetches from offsets `4` up to, but not including, `1`, reversed.

**Slice assignment: S[i:j:k] = I**

- Slice assignment is similar to deleting and then inserting where deleted.
- Iterables assigned to basic slices `S[i:j]` need not match in size.
- Iterables assigned to extended slices `S[i:j:k]` must match in size.

**Other**

- Concatenation, repetition, and slicing return new objects (though not always for tuples).

# Specific Built-in Types

This section covers numbers, strings, lists, dictionaries, tuples, files, sets, and other core built-in types. Its subsections give details common to both Python 3.X and 2.X. In general, all the compound datatypes covered here (e.g., lists, dictionaries, and tuples) can nest inside each other arbitrarily and as deeply as

required. Sets may participate in nesting as well, but may contain only immutable objects.

## Numbers

Numbers are *immutable* (unchangeable) values, supporting numeric operations. This section covers basic number types (integers, floating-point), as well as more advanced types (complex, decimals, and fractions).

### Literals and creation

Numbers are written in a variety of numeric literal forms, and created by some built-in operations:

`1234`, `-24`, `+42`, `0`
: Integers (unlimited precision).[1]

`1.23`, `3.14e-10`, `4E210`, `4.0e+210`, `1.`, `.1`
: Floating-point (normally implemented as C doubles in CPython).

`0o177`, `0x9ff`, `0b1111`
: Octal, hex, and binary literals for integers.[2]

`3+4j`, `3.0+4.0j`, `3J`
: Complex numbers.

1. In Python 2.X, there is a distinct type named `long` for unlimited-precision integers; `int` is for normal integers with precision that is usually limited to 32 bits. Long objects may be coded with a trailing "L" (e.g., `99999L`), although integers are automatically promoted to longs if they require the extra precision. In 3.X, the `int` type provides unlimited precision and so subsumes both the 2.X `int` and `long` types; the "L" literal syntax is removed in 3.X.
2. In Python 2.X, octal literals may also be written with just a leading zero —`0777` and `0o777` are equivalent. In 3.X, only the latter form is supported for octal.

`decimal.Decimal('1.33')`, `fractions.Fraction(4, 3)`
: Module-based types: decimal, fraction.

`int(9.1)`, `int('-9')`, `int('1111', 2)`, `int('0b1111', 0)`, `float(9)`, `float('1e2')`, `float('-.1')`, `complex(3, 4.0)`
: Create numbers from other objects, or from strings with possible base conversion. Conversely, `hex(N)`, `oct(N)`, and `bin(N)` create digit strings for integers, and string formatting makes general strings for numbers. See also "String formatting", "Type Conversions", and "Built-in Functions".

## Operations

Number types support all *number operations* (see Table 6 on page 19). In mixed-type expressions, Python converts operands up to the type of the "highest" type, where integer is lower than floating-point, which is lower than complex. As of Python 3.0 and 2.6, integer and floating-point objects also have a handful of type-specific *methods* and other *attributes*; see Python's Library Reference manual for details:

```
>>> (2.5).as_integer_ratio()           # float attrs
(5, 2)
>>> (2.5).is_integer()
False

>>> (2).numerator, (2).denominator     # int attrs
(2, 1)
>>> (255).bit_length(), bin(255)       # 3.1+ method
(8, '0b11111111')
```

## Decimal and fraction

Python provides two additional numeric types in standard library modules—*decimal* is a fixed-precision, floating-point number, and *fraction* is a rational type that keeps numerator and denominator explicitly. Both may be used to address inaccuracies of floating-point arithmetic:

```
>>> 0.1 - 0.3
-0.19999999999999998
```

```
>>> from decimal import Decimal
>>> Decimal('0.1') - Decimal('0.3')
Decimal('-0.2')

>>> from fractions import Fraction
>>> Fraction(1, 10) - Fraction(3, 10)
Fraction(-1, 5)

>>> Fraction(1, 3) + Fraction(7, 6)
Fraction(3, 2)
```

Fractions automatically simplify results. By fixing precision and supporting various truncation and rounding protocols, decimals are useful for monetary applications. See the Python Library Reference for details.

### Other numeric types

Python also includes a *set* type (described in "Sets"). Additional numeric types such as optimized vectors and matrixes are available as third-party open source extensions (e.g., see the *NumPy* package at *http://www.numpy.org*). The third-party domain also includes support for visualization, statistical tools, extended precision floating-point math, and more (see the Web).

## Strings

The normal `str` string object is an *immutable* (unchangeable) *sequence* of characters accessed by *offset* (position). Its *characters* are code point ordinals in the underlying character set, and individual characters are string objects of length 1.

The full string object model varies across lines.

*Python 3.X* has three string types with similar interfaces:

`str`
: An immutable sequence of characters, used for all text—both ASCII and richer Unicode.

`bytes`
: An immutable sequence of short integers, used for the byte values of binary data.

`bytearray`
: A mutable variant of bytes.

*Python 2.X* instead has two string types with similar interfaces:

`str`
: An immutable sequence of characters, used for both byte oriented (8-bit) text and binary data.

`unicode`
: An immutable sequence of characters, used for possibly-richer Unicode text.

Python 2.X (as of 2.6) also has the Python 3.X `bytearray` type as a back-port from 3.X, but it does not impose as sharp a distinction between text and binary data. (It may be mixed with text strings freely in 2.X.)

For Unicode support in both 3.X and 2.X, see "Unicode Strings". Most of the remainder of this section pertains to all string types, but see "String methods", "Unicode Strings", and "Built-in Functions" for more on `bytes` and `bytearray`.

## Literals and creation

String literals are written as a series of characters in quotes, optionally preceded with a designator character, and in all string literal forms an empty string is coded as adjacent quotes. Various built-in operations also return new strings:

`'Python"s', "Python's"`
: Single and double quotes work the same, and each can embed unescaped quotes of the other kind.

`"""This is a multiline block"""`
: Triple-quoted blocks collect multiple lines of text into a single string, with end-of-line markers (`\n`) inserted between the original quoted lines.

`'Python\'s\n'`
: Backslash escape code sequences (see Table 7) are replaced with the special-character code point values they represent (e.g., `'\n'` is an ASCII character with decimal code-point value `10`).

`"This" "is" "concatenated"`
: Adjacent string constants are concatenated. Hint: this form may span lines if parenthesized.

`r'a raw\string', R'another\one'`
: Raw strings: backslashes are retained literally (except at the end of a string). Useful for regular expressions and Windows (DOS) directory paths: e.g., `r'c:\dir1\file'`.

`hex()`, `oct()`, `bin()`
: Create hex/octal/binary digit strings from integer numbers. See "Numbers" and "Built-in Functions".

The following literal forms and calls make specialized strings described in "Unicode Strings":

`b'...'`
: `bytes` string literal in Python 3.X: sequence of 8-bit byte values representing raw binary data. For 3.X compatibility, this form is also available in Python 2.6 and 2.7, where it simply creates a normal `str` string. See "String methods", "Unicode Strings", and "Built-in Functions".

`bytearray(...)`
: `bytearray` string construction: a mutable variant of `bytes`. Available in Python 3.X, and in Python 2.X as of 2.6. See "String methods", "Unicode Strings", and "Built-in Functions".

`u'...'`
: Unicode string literal in Python 2.X: a sequence of Unicode code points. For 2.X compatibility, this form is also available in Python 3.X as of 3.3, where it simply creates a normal `str` string (but normal string literals and `str` strings support Unicode text in Python 3.X). See "Unicode Strings".

`str()`, `bytes()`, `bytearray()` (and `unicode()` in 2.X only)
: Create strings from objects, with possible Unicode encoding/decoding in Python 3.X. See "Built-in Functions".

String literals may contain escape sequences taken from Table 7 to represent special characters.

*Table 7. String constant escape codes*

| Escape | Meaning | Escape | Meaning |
|---|---|---|---|
| `\`*`newline`* | Ignored continuation | `\t` | Horizontal tab |
| `\\` | Backslash (\) | `\v` | Vertical tab |
| `\'` | Single quote (') | `\N{`*`id`*`}` | Unicode dbase id |
| `\"` | Double quote (") | `\u`*`hhhh`* | Unicode 16-bit hex |
| `\a` | Bell | `\U`*`hhhhhhhh`* | Unicode 32-bit hex[a] |
| `\b` | Backspace | `\x`*`hh`* | Hex (at most 2 digits) |
| `\f` | Formfeed | `\`*`ooo`* | Octal (up to 3 digits) |
| `\n` | Line feed | `\0` | Null (not end of string) |
| `\r` | Carriage return | `\`*`other`* | Not an escape |

[a] `\U`*`hhhhhhhh`* takes exactly eight hexadecimal digits (h); both `\u` and `\U` can be used only in Unicode string literals.

## Operations

All string types support all *sequence operations* (see Table 3), plus string-specific *methods* (described in "String methods"). In addition, the `str` type supports string *formatting* `%` expressions and template substitution (discussed next), and the `bytearray` type supports *mutable sequence operations* (Table 4, plus extra list-like methods). Also see the `re` string pattern-matching module in "The re Pattern-Matching Module", and string-related, built-in functions in "Built-in Functions".

## String formatting

In both Python 3.X and 2.X (as of 3.0 and 2.6), normal `str` strings support two different flavors of string formatting—operations that format objects according to format description strings:

- The original expression (all Python versions), coded with the `%` operator: *`fmt`*`%` `(`*`values`*`)`
- The newer method (3.0, 2.6, and later), coded with call syntax: *`fmt`*`.format(`*`values`*`)`

Both produce new strings based on possibly type-specific substitution codes. Their results may be displayed, or assigned to variables for later use:

```
>>> '%s, %s, %.2f' % (42, 'spam', 1 / 3.0)
'42, spam, 0.33'

>>> '{0}, {1}, {2:.2f}'.format(42, 'spam', 1 / 3.0)
'42, spam, 0.33'
```

Although the method call seems to have evolved more rapidly in recent years, the expression is used extensively in existing code, and both forms are still fully supported. Moreover, although some view the method form as marginally more mnemonic and consistent, the expression is often simpler and more concise. As these two forms are largely just minor variations on a theme of equivalent functionality and complexity, there is today no compelling reason to recommend one over the other.

## String formatting expression

String formatting *expressions* replace `%` targets in the string on the left of the `%` operator, with values on the right (similar to C's `sprintf`). If more than one value is to be replaced, they must be coded as a tuple to the right of the `%` operator. If just one item is to be replaced, it can be coded as a single value or one-item tuple on the right (nest tuples to format a tuple itself). If key names are used on the left, a dictionary must be supplied on the right, and `*` allows width and precision to be passed in dynamically:

```
>>> 'The knights who say %s!' % 'Ni'
'The knights who say Ni!'
>>> '%d %s, %d you' % (1, 'spam', 4.0)
'1 spam, 4 you'
>>> '%(n)d named %(x)s' % {'n': 1, 'x': "spam"}
'1 named spam'
>>> '%(n).0E => [%(x)-6s]' % dict(n=100, x='spam')
'1E+02 => [spam  ]'
>>> '%f, %.2f, %+.*f' % (1/3.0, 1/3.0, 4, 1/3.0)
'0.333333, 0.33, +0.3333'
```

### Formatting expression syntax

In the format string on the left of the `%` operator, substitution targets have the following general format, all but the last component of which is optional (text outside such substitution targets is retained verbatim):

`%[(`*`keyname`*`)][`*`flags`*`][`*`width`*`][.`*`prec`*`]`*`typecode`*

In this substitution target syntax:

*`keyname`*
: References an item in the expected dictionary, in parentheses.

*`flags`*
: Can be – (left-justify), + (numeric sign), a space (use a blank before positive numbers and a – for negatives ), and `0` (zero fill).

*`width`*
: The total minimum field width (use `*` to fetch from values).

*`prec`*
: Gives the number of digits (i.e., precision) to include after `.` (use `*` to fetch from values).

*`typecode`*
: A character from Table 8.

Both *width* and *prec* can be coded as a * to force their values to be taken from the next item in the values to the right of the % operator when sizes are not known until runtime. Hint: %s generically converts any object type to its print representation string.

*Table 8. % string formatting type codes*

| Code | Meaning | Code | Meaning |
|---|---|---|---|
| s | String (or any object, uses str()) | X | x with uppercase |
| r | s, but uses repr(), not str() | e | Floating-point exponent |
| c | Character (int or str) | E | e with uppercase |
| d | Decimal (base 10 integer) | f | Floating-point decimal |
| i | Integer | F | f with uppercase |
| u | Same as d (obsolete) | g | Floating-point e or f |
| o | Octal (base 8 integer) | G | Floating-point E or F |
| x | Hex (base 16 integer) | % | Literal '%' (coded as %%) |

## String formatting method

The formatting *method* call works similar to the prior section's expression, but is invoked with normal method-call syntax on the format string object, which identifies substitution targets with {} syntax instead of %.

Substitution targets in the format string may name method-call arguments by position or keyword name; may further reference argument attributes, keys, and offsets; may accept default formatting or provide explicit type codes; and may nest target syntax to pull values from the arguments list:

```
>>> 'The knights who say {0}!'.format('Ni')
'The knights who say Ni!'
>>> '{0} {1}, {2:.0f} you'.format(1, 'spam', 4.0)
'1 spam, 4 you'
>>> '{n} named {x:s}'.format(n=1, x="spam")
'1 named spam'
>>> '{n:.0E} => [{x:<6s}]'.format(
                              **dict(n=100, x='spam'))
```

```
'1E+02 => [spam  ]'
>>> '{:f}, {:.2f}, {:+.{}f}'.format(
                                1/3.0, 1/3.0, 1/3.0, 4)
'0.333333, 0.33, +0.3333'
```

Most `format` method applications have equivalents in `%` expression usage patterns as shown in the preceding section (e.g., dictionary key and `*` value references), although the method allows some operations to be coded inside the format string itself:

```
>>> import sys   # Method vs expr: attr, key, index

>>> fmt = '{0.platform} {1[x]} {2[0]}'
>>> fmt.format(sys, dict(x='ham'), 'AB')
'win32 ham A'

>>> fmt = '%s %s %s'
>>> fmt % (sys.platform, dict(x='ham')['x'], 'AB'[0])
'win32 ham A'
```

As of Python 3.1 and 2.7, a `,` (comma) preceding an integer or floating-point designation in *`typecode`*, formally described in "Formatting method syntax", inserts thousands-separator commas, and a *`typecode`* of `%` formats a percentage (tools not present in the formatting expression itself, but straightforward to code as reusable functions):

```
>>> '{0:,d}'.format(1000000)
'1,000,000'
>>> '{0:13,.2f}'.format(1000000)
' 1,000,000.00'
>>> '{0:%} {1:,.2%}'.format(1.23, 1234)
'123.000000% 123,400.00%'
```

Also as of Python 3.1 and 2.7, field numbers are automatically numbered sequentially if omitted from the *`fieldname`* also described in "Formatting method syntax"—the following three have the same effect, although auto-numbered fields may be less readable if many fields are present:

```
>>> '{0}/{1}/{2}'.format('usr', 'home', 'bob')
'usr/home/bob'
>>> '{}/{}/{}'.format('usr', 'home', 'bob')   # Auto
```

```
'usr/home/bob'
>>> '%s/%s/%s' % ('usr', 'home', 'bob')       # Expr
'usr/home/bob'
```

A single object may also be formatted with the `format(`*`object`*`,` *`formatspec`*`)` built-in function (see "Built-in Functions"), which is employed by the string `format` method, and whose behavior may be implemented with the `__format__` operator-overloading method in classes (see "Operator Overloading Methods").

### Formatting method syntax

Substitution targets in strings used for format method calls take the following general form, all four parts of which are optional, and must appear without intervening spaces (used here for clarity):

{*`fieldname component !conversionflag :formatspec`*}

In this substitution target syntax:

*`fieldname`*
: An optional number or keyword identifying an argument, which may be omitted to use relative argument numbering in 2.7, 3.1, and later.

*`component`*
: A string of zero or more `.`*`name`* or `[`*`index`*`]` references used to fetch attributes and indexed values of the argument, which may be omitted to use the whole argument value.

*`conversionflag`*
: Introduced by a `!` if present, which is followed by `r`, `s`, or `a` to call `repr()`, `str()`, or `ascii()` built-in functions on the value, respectively.

*`formatspec`*
: Introduced by a `:` if present, and consists of text that specifies how the value should be presented, including details such as field width, alignment, padding, decimal precision, and so on, and ending with an optional datatype code.

The nested *formatspec* component after the colon character has a syntax of its own, formally described as follows (brackets in this denote optional components and are not coded literally):

```
[[fill]align][sign][#][0][width][,][.prec][typecode]
```

In this *formatspec* nested syntax:

*fill*
: Can be any fill character other than { or }.

*align*
: May be <, >, =, or ^, for left alignment, right alignment, padding after a sign character, or centered alignment, respectively.

*sign*
: May be +, –, or space.

, (comma)
: Requests a comma for a thousands separator as of Python 3.1 and 2.7.

*width* and *prec*
: Much as in the % expression, and the *formatspec* may also contain nested {} format strings having a *fieldname* only, to take values from the arguments list dynamically (much like the * in formatting expressions). A 0 preceding *width* enables sign-aware zero padding (similar to *fill*), and a # enables an alternative conversion (if available).

*typecode*
: Largely the same as in % expressions and listed in Table 8, but the format method has an extra b type code used to give integers in binary format (much like using the bin built-in); has an extra % type code to format percentages as of Python 3.1 and 2.7; and uses only d for base-10 integers (i or u are not used).

Note that unlike the expression's generic %s, the method's s type code requires a *string* object argument; omit the type code to accept any type generically in the method.

### Template string substitution

As of Python 2.4, another form of string substitution is provided as an alternative to the string formatting expression and method described in the prior sections. In full formatting, substitution is achieved with the `%` operator or `str.format()` method (all four of the following return `'2: PR5E'`):

```
'%(page)i: %(book)s' % {'page': 2, 'book': 'PR5E'}
'%(page)i: %(book)s' % dict(page=2, book='PR5E')

'{page}: {book}'.format(**dict(page=2, book='PR5E'))
'{page}: {book}'.format(page=2, book='PR5E')
```

For simpler substitution tasks, a `Template` class in `string` uses `$` to indicate a substitution:

```
>>> import string
>>> t = string.Template('$page: $book')
>>> t.substitute({'page': 2, 'book': 'PR5E'})
'2: PR5E'
```

Substitution values can be provided as keyword arguments or dictionary keys:

```
>>> s = string.Template('$who likes $what')
>>> s.substitute(who='bob', what=3.14)
'bob likes 3.14'
>>> s.substitute(dict(who='bob', what='pie'))
'bob likes pie'
```

A `safe_substitute` method ignores missing keys rather than raising an exception:

```
>>> t = string.Template('$page: $book')
>>> t.safe_substitute({'page': 3})
'3: $book'
```

### String methods

In addition to the `format()` method described earlier, string method calls provide higher-level text processing tools beyond string expressions. Table 9 lists available string method calls; in this table, *S* is any string object (technically, a 3.X `str`). String

methods that modify text always return a new string and never modify the object in-place (strings are immutable).

For more details on methods in the table, see the functional area description sections ahead, or run a `help(str.`*`method`*`)` interactively. Hint: this list can vary across Python releases; to see yours, try:

```
sorted(x for x in dir(str) if not x.startswith('__'))
```

See also the `re` module in "The re Pattern-Matching Module" for pattern-based equivalents to some string type methods.

*Table 9. Python 3.X string method calls*

`S.capitalize()`

`S.casefold()` (as of Python 3.3)

`S.center(`*`width`*`, [,`*`fill`*`])`

`S.count(`*`sub`*`[,`*`start`*`[,`*`end`*`]])`

`S.encode([`*`encoding`*`[,`*`errors`*`]])`

`S.endswith(`*`suffix`*`[,`*`start`*`[,`*`end`*`]])`

`S.expandtabs([`*`tabsize`*`])`

`S.find(`*`sub`*`[,`*`start`*`[,`*`end`*`]])`

`S.format(*`*`args`*`, **`*`kwargs`*`)`

`S.format_map(`*`mapping`*`)` (as of Python 3.2)

`S.index(`*`sub`*`[,`*`start`*`[,`*`end`*`]])`

`S.isalnum()`

`S.isalpha()`

`S.isdecimal()`

`S.isdigit()`

`S.isidentifier()`

`S.islower()`

`S.isnumeric()`

`S.isprintable()`

*S*.isspace()

*S*.istitle()

*S*.isupper()

*S*.join(*iterable*)

*S*.ljust(*width*[, *fill*])

*S*.lower()

*S*.lstrip([*chars*])

*S*.maketrans(*x*[, *y*[, *z*]])

*S*.partition(*sep*)

*S*.replace(*old*, *new*[, *count*])

*S*.rfind(*sub*[, *start*[, *end*]])

*S*.rindex(*sub*[, *start*[, *end*]])

*S*.rjust(*width*[, *fill*])

*S*.rpartition(*sep*)

*S*.rsplit([*sep*[, *maxsplit*]])

*S*.rstrip([*chars*])

*S*.split([*sep*[, *maxsplit*]])

*S*.splitlines([*keepends*])

*S*.startswith(*prefix*[, *start*[, *end*]])

*S*.strip([*chars*])

*S*.swapcase()

*S*.title()

*S*.translate(*map*)

*S*.upper()

*S*.zfill(*width*)

### byte and bytearray methods

Python 3.X `bytes` and `bytearray` string types have method sets similar to that of the normal `str` type given in the preceding section, but do not overlap exactly due to differing roles. (`str` is Unicode text, `bytes` is raw binary data, and `bytearray` is mutable.) In the following, run in Python 3.3, `set(dir(X)) - set(dir(Y))` computes attributes unique to *X*:

```
>>> set(dir(str)) - set(dir(bytes))
{'__rmod__', 'encode', 'isnumeric', 'format',
'isidentifier', 'isprintable', 'isdecimal',
'format_map', '__mod__', 'casefold'}

>>> set(dir(bytes)) - set(dir(str))
{'decode', 'fromhex'}

>>> set(dir(bytearray)) - set(dir(bytes))
{'extend', 'remove', 'insert', 'append', 'pop',
'__iadd__', 'reverse', 'clear', '__imul__',
'copy', '__setitem__', '__alloc__', '__delitem__'}
```

Of note:

- `str` does not support Unicode *decoding* (it is already-decoded text), but may be *encoded* to `bytes`.
- `bytes` and `bytearray` do not support Unicode *encoding* (they are raw bytes, including both media and already-encoded text), but may be *decoded* to `str`.
- `bytes` and `bytearray` do not support string *formatting* (implemented by `str.format` and the `%` operator's `__mod__` and `__rmod__`).
- `bytearray` has extra mutable in-place methods and operators similar to `list` (e.g., `append`, `+=`).

See "byte and bytearray strings" for more on byte string operations. Also see "Unicode Strings" for more on string type models, and "Built-in Functions" for more on construction calls.

**NOTE**

The set of string methods available in *Python 2.X* varies slightly (e.g., there is a `decode` method for 2.X's different Unicode type model). The Python 2.X `unicode` string type has a nearly identical interface to 2.X `str` objects. For more details, consult the Python 2.X Library Reference, or run `dir(str)` or `help(str.`*`method`*`)` interactively.

The next few sections go into more detail on selected methods listed in Table 9, grouped by functional area. In all of the documented calls that return a string result, the result is a *new string* (because strings are immutable, they are never modified in-place.) Whitespace in this coverage means spaces, tabs, and end-of-line characters (everything in `string.whitespace`).

## Searching methods

*S*`.find(`*sub* `[, `*start* `[, `*end*`]])`
: Returns offset of the first occurrence of string *sub* in *S*, between offsets *start* and *end* (which default to `0` and `len(`*S*`)`, the entire string). Returns `-1` if not found. Hint: also see the `in` membership operator (in Table 3), which may be used to test substring membership in a string.

*S*`.rfind(`*sub* `[, `*start* `[, `*end*`]])`
: Like `find`, but scans from the end (right to left).

*S*`.index(`*sub* `[, `*start* `[, `*end*`]])`
: Like `find`, but raises `ValueError` if not found instead of returning `-1`.

*S*`.rindex(`*sub* `[, `*start* `[, `*end*`]])`
: Like `rfind`, but raises `ValueError` if not found instead of returning `-1`.

*S*`.count(`*sub* `[, `*start* `[, `*end*`]])`
: Counts the number of nonoverlapping occurrences of *sub* in *S*, from offsets *start* to *end* (defaults: `0`, `len(`*S*`)`).

*S*.startswith(*sub* [, *start* [, *end*]])
: True if string *S* starts with substring *sub*. *start* and *end* give optional begin and end points for matching *sub*.

*S*.endswith(*sub* [, *start* [, *end*]])
: True if string *S* ends with substring *sub*. *start* and *end* give optional begin and end points for matching *sub*.

## Splitting and joining methods

*S*.split([*sep* [, *maxsplit*]])
: Returns a list of the words in the string *S*, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done. If *sep* is not specified or is None, any whitespace string is a separator. `'a*b'.split('*')` yields `['a','b']`. Hint: use `list(S)` to convert a string to a list of characters (e.g., `['a','*','b']`).

*S*.join(*iterable*)
: Concatenates an iterable (e.g., list or tuple) of strings into a single string, with *S* added between each item. *S* can be '' (an empty string) to convert an iterable of characters to a string (`'*'.join(['a','b'])` yields `'a*b'`).

*S*.replace(*old*, *new* [, *count*])
: Returns a copy of string *S* with all occurrences of substring *old* replaced by *new*. If *count* is passed, the first *count* occurrences are replaced. This works like a combination of `x=S.split(old)` and `new.join(x)`.

*S*.splitlines([*keepends*])
: Splits string *S* on line breaks, returning lines list. The result does not retain line break characters unless *keepends* is true.

## Formatting methods

*S*.format(**args*, ***kwargs*), *S*.format_map(*mapping*)
: See section "String formatting". In Python 3.2 and later, *S*.format_map(*M*) is like *S*.format(***M*), but *M* is not copied.

`S.capitalize()`
: Capitalizes the first character of string `S`, and lowercases its other characters.

`S.expandtabs([tabsize])`
: Replaces tabs in string `S` with `tabsize` spaces (default is 8).

`S.strip([chars])`
: Removes leading and trailing whitespace from string `S` (or characters in `chars` if passed).

`S.lstrip([chars])`
: Removes leading whitespace from string `S` (or characters in `chars` if passed).

`S.rstrip([chars])`
: Removes trailing whitespace from string `S` (or characters in `chars` if passed).

`S.swapcase()`
: Converts all lowercase letters to uppercase, and vice versa.

`S.upper()`
: Converts all letters to uppercase.

`S.lower()`
: Converts all letters to lowercase.

`S.casefold()`
: In Python 3.3 and later, returns a version of `S` suitable for caseless comparisons; like `S.lower()`, but also intelligently lowercases some Unicode characters.

`S.ljust(width [, fill])`
: Left-justifies string `S` in a field of the given `width`; pads on right with character `fill` (which defaults to a space). The string formatting expression and method can achieve similar effects.

`S.rjust(width [, fill])`
: Right-justifies string `S` in a field of the given `width`; pads on left with character `fill` (which defaults to a space). The

string formatting expression and method can achieve similar effects.

*S*.center(*width* [, *fill*])
: Centers string *S* in a field of the given *width*; pads on left and right with character *fill* (which defaults to a space). String formatting can achieve similar effects.

*S*.zfill(*width*)
: Pads string *S* on left with zero digits to produce a string result of the desired *width* (can also achieve with string formatting).

*S*.translate(*table* [, *deletechars*])
: Deletes all characters from string *S* that are in *deletechars* (if present), and then translates the characters using *table*, a 256-character string giving the translation for each character value indexed by its ordinal.

*S*.title()
: Returns a title-cased version of the string: words start with uppercase characters; all remaining cased characters are lowercase.

### Content test methods

*S*.is*()
: The `is*()` Boolean tests work on strings of any length. They test the content of strings for various categories (and always return `False` for an empty).

### The original string module

Starting in Python 2.0, most of the string-processing functions previously available in the standard `string` module became available as methods of string objects. If *X* references a string object, a `string` module function call such as:

```
import string
res = string.replace(X, 'span', 'spam')
```

is usually equivalent in Python 2.0 and later to a string method call such as:

```
res = X.replace('span', 'spam')
```

But the string method call form is preferred and quicker, and string methods require no module imports. Note that the `string.join(`*`iterable`*`,` *`delim`*`)` operation becomes a method of the delimiter string *`delim`*`.join(`*`iterable`*`)`. All these functions are removed from the `string` module in Python 3.X: use the equivalent string object methods instead. See "The string Module" for this module's remaining content.

## Unicode Strings

All text is Unicode text, including text encoded with one character per byte (8 bits) in the ASCII scheme. Python supports richer character sets and encoding schemes with *Unicode*—strings which may use multiple bytes to represent characters in memory, and which translate text to and from various encodings on files. This support differs in Python lines. Python 3.X treats all text as Unicode and represents binary data separately, while Python 2.X distinguishes 8-bit text (and data) from possibly wider Unicode text:

*In Python 3.X*

The normal `str` type and `'ccc'` literal represents all text, both 8-bit and richer Unicode. `str` is an immutable sequence of *characters*—decoded Unicode code points (ordinal identifiers) in memory.

A separate `bytes` type and `b'ccc'` literal represents binary data byte values, including media and encoded Unicode text. `bytes` is an immutable sequence of small *integers* (8-bit byte values), but supports most `str` operations, and prints content as ASCII characters when possible. An additional `bytearray` type is a mutable variant of `bytes`, with extra list-like methods for in-place changes.

Also in 3.X, normal *files* created by `open()` imply `str` and `bytes` objects for content in text and binary mode, respectively. In text mode, files automatically encode on output and decode on input.

As of Python 3.3, 2.X's `u'ccc'` Unicode literal form is also available for backward compatibility with 2.X code (it creates a 3.X `str`).

*In Python 2.X*

The normal `str` type and `'ccc'` literal represents the byte values of both 8-bit oriented text and binary data, and a separate `unicode` type and `u'ccc'` literal represents the code points of possibly wider Unicode text. Both string types are immutable sequences, and have nearly identical operations.

Also in 2.X, normal *files* created by `open()` are byte-oriented, and a `codecs.open()` supports reading and writing files containing Unicode text with encoding and decoding on transfers.

As of Python 2.6, 3.X's `b'ccc'` bytes literal is also available for forward compatibility with 3.X code (it creates a 2.X `str`), and 3.X's mutable `bytearray` is present though less type specific.

## Unicode support in Python 3.X

Python 3.X allows non-ASCII characters to be coded in strings with hex (`\x`) and both 16- and 32-bit Unicode (`\u`, `\U`) escapes. In addition, `chr()` supports Unicode character codes:

```
>>> 'A\xE4B'
'AäB'
>>> 'A\u00E4B'
'AäB'
>>> 'A\U000000E4B'
'AäB'
>>> chr(0xe4)
'ä'
```

Normal strings may be encoded into raw bytes and raw bytes may be decoded into normal strings, using either default or explicit encodings (and optional error policy: see `str()` in "Built-in Functions"):

```
>>> 'A\xE4B'.encode('latin-1')
b'A\xe4B'
>>> 'A\xE4B'.encode()
b'A\xc3\xa4B'
>>> 'A\xE4B'.encode('utf-8')
b'A\xc3\xa4B'

>>> b'A\xC3\xA4B'.decode('utf-8')
'AäB'
```

File objects also automatically encode on output and decode on input in text mode (but not in binary mode), and accept an encoding name to override the default encoding (see `open()` in "Built-in Functions"):

```
>>> S = 'A\xE4B'
>>> open('uni.txt', 'w', encoding='utf-8').write(S)
3
>>> open('uni.txt', 'rb').read()
b'A\xc3\xa4B'
>>>
>>> open('uni.txt', 'r', encoding='utf-8').read()
'AäB'
```

As of release 3.3, Python 3.X also supports 2.X's `u'ccc'` Unicode literal form for backward compatibility, but it is a synonym for `'ccc'`, and creates a normal 3.X `str` string.

In both 3.X and 2.X, you may also embed Unicode content in program source files directly: use a line of the following form as line 1 or 2 of your file, if needed to override Python's UTF-8 default:

```
# -*- coding: latin-1 -*-
```

### byte and bytearray strings

Python 3.X `bytes` and `bytearray` string objects represent 8-bit binary data (including encoded Unicode text); are printed as ASCII text when possible; and support most normal `str` string operations including methods and sequence operations (but not string formatting):

```
>>> B = b'spam'
>>> B
b'spam'
>>> B[0]                # Sequence ops
115
>>> B + b'abc'
b'spamabc'
>>> B.split(b'a')       # Methods
[b'sp', b'm']
>>> list(B)             # Sequence of int
[115, 112, 97, 109]
```

`bytearray` additionally supports list-like mutable operations:

```
>>> BA = bytearray(b'spam')
>>> BA
bytearray(b'spam')
>>> BA[0]
115
>>> BA + b'abc'
bytearray(b'spamabc')
>>> BA[0] = 116         # Mutability
>>> BA.append(115)      # List methods
>>> BA
bytearray(b'tpams')
```

Formally, both `bytes` and `bytearray` support *sequence operations* (see Table 3), as well as type-specific *methods* described earlier in "byte and bytearray methods". `bytearray` additionally supports *mutable sequence operations* (see Table 4). See also type constructor calls in "Built-in Functions".

Python 2.6 and 2.7 have `bytearray` but not `bytes`—3.X's `b'ccc'` is supported for forward compatibility, but is simply a synonym for `'ccc'`, and creates a normal 2.X `str` string.

### Unicode support in Python 2.X

In Python 2.X, Unicode strings are written as `u'ccc'`, which creates a `unicode` type object. (In Python 3.X, the normal string type and literal are used for Unicode.) Arbitrary Unicode characters can be written using a special escape sequence, `\uHHHH`, where `HHHH` is a four-digit hexadecimal number from `0000` to `FFFF`. The traditional `\x`*HH* escape sequence can also be used, and octal escapes can be used for characters up to `+01FF`, which is represented by `\777`.

`unicode` supports both string methods and *sequence operations* (see Table 3). Normal and Unicode string objects can be mixed in Python 2.X; combining 8-bit and Unicode strings always coerces to Unicode, using the default ASCII encoding (e.g., the result of `'a' + u'bc'` is `u'abc'`). Mixed-type operations assume the 8-bit string contains 7-bit U.S. ASCII data (and raise an error for non-ASCII characters). The built-in `str()` and `unicode()` functions can be used to convert between normal and Unicode strings, and the `encode()` and `decode()` string methods apply and undo Unicode encodings.

Available related modules and built-in functions include `codecs.open()`, whose files perform Unicode encoding translations on data transfers, much like 3.X's built-in `open()` function files.

## Lists

Lists are *mutable* (changeable) *sequences* of object references accessed by *offset* (position).

### Literals and creation

List literals are written as a comma-separated series of values enclosed in square brackets, and various operations construct lists dynamically:

`[]`
: An empty list.

`[0, 1, 2, 3]`
: A four-item list: indexes `0` through `3`.

`L = ['spam', [42, 3.1415], 1.23, {}]`
: Nested sublists: `L[1][0]` fetches 42.

`L = list('spam')`
: Creates a list of all items in any iterable, by calling the type constructor function.

`L = [x ** 2 for x in range(9)]`
: Creates a list by collecting expression results during iteration (list comprehension).

## Operations

Operations include all *sequence operations* (see Table 3), plus all *mutable sequence operations* (see Table 4), plus the following list-specific *methods*, in all of which `L` stands for any list object:

`L.append(X)`
: Inserts the single object `X` at the end of `L`, changing the list in-place.

`L.extend(I)`
: Inserts each item in any iterable `I` at the end of `L` in-place (like an in-place `+`). Similar to `L[len(L):] = I`. Hint: use `L[:0] = I` to prepend all items in `I`.

`L.sort(key=None, reverse=False)`
: Sorts `L` in-place, in ascending order by default. If passed, `key` specifies a function of one argument that is used to extract or compute a comparison value from each list element. If `reverse` is passed and `true`, the list elements are sorted as if each comparison were reversed. For example: `L.sort(key=str.lower, reverse=True)`. See also `sorted()` in "Built-in Functions".

`L.reverse()`
: Reverses items in `L` in-place. See also `reversed()` in "Built-in Functions".

`L.index(X[, i[, j]])`
: Returns the index of the first occurrence of object `X` in `L`; raises an exception if not found. This is a search method. If `i` and possibly `j` are passed, it returns the smallest `k` such that `L[k] == X` and `i <= k < j`, where `j` defaults to `len(L)`.

`L.insert(i, X)`
: Inserts single object `X` into `L` at offset `i` (like `L[i:i] = [X]`, for positive or negative `i`). Hint: use `L[i:i] = I` to insert all items in any iterable `I` at offset `i`.

`L.count(X)`
: Returns the number of occurrences of `X` in `L`.

`L.remove(X)`
: Deletes the first occurrence of object `X` from `L`; raises an exception if not found. Same as `del L[L.index(X)]`.

`L.pop([i])`
: Deletes and returns the last (or offset `i`) item in `L`. Useful with `append()` to implement stacks. Same as `x=L[i]; del L[i]; return x`, where `i` defaults to `-1`, the last item.

`L.clear()`
: Removes all items from `L`. Available in 3.X (only), as of 3.3.

`L.copy()`
: Make a top-level (shallow) copy of `L`. Available in 3.X (only), as of 3.3

**NOTE**

*In Python 2.X*, the list `sort` method signature is:

```
L.sort(cmp=None, key=None, reverse=False)
```

where `cmp` is a two-argument comparison function, which returns a value less than, equal to, or greater than zero to denote a less, equal, and greater result. The comparison function is removed in 3.X because it was typically used to map sort values and reverse sort order—use cases supported by the remaining two arguments.

## List comprehension expressions

A list literal enclosed in square brackets (`[...]`) can be a simple list of expressions or a list comprehension expression of the following form:

```
[expr for target1 in iterable1 [if condition1]
      for target2 in iterable2 [if condition2] ...
      for targetN in iterableN [if conditionN] ]
```

List comprehensions construct result lists: they collect all values of expression *`expr`*, for each iteration of all nested `for` loops, for which each optional *`condition`* is true. The second through $N^{th}$ `for` loops and all `if` parts are optional, and *`expr`* and each *`condition`* can use variables assigned by nested `for` loops. Names bound (assigned) inside a list comprehension are created in the scope enclosing the comprehension expression in 2.X, but are localized to the comprehension in 3.X. Comprehensions may be nested arbitrarily.

Comprehensions are similar to the `map()` built-in function (in 3.X only, `map()` requires `list()` to force results generation for display, because it both iterates and is iterable itself; in 2.X `map()` returns a list):

```
>>> [ord(x) for x in 'spam']
[115, 112, 97, 109]
>>> list(map(ord, 'spam'))       # Use list() in 3.X
[115, 112, 97, 109]
```

However, comprehensions can often avoid creating a temporary helper function:

```
>>> [x ** 2 for x in range(5)]
[0, 1, 4, 9, 16]
>>> list(map((lambda x: x ** 2), range(5)))
[0, 1, 4, 9, 16]
```

Comprehensions with conditions are similar to `filter()` (also an iterable in 3.X only):

```
>>> [x for x in range(5) if x % 2 == 0]
[0, 2, 4]
>>> list(filter((lambda x: x % 2 == 0), range(5)))
[0, 2, 4]
```

Comprehensions with nested `for` loops are similar to the normal `for` statement:

```
>>> [x + y for x in range(3) for y in [10, 20, 30]]
[10, 20, 30, 11, 21, 31, 12, 22, 32]

>>> res = []
>>> for x in range(3):
...     for y in [10, 20, 30]:
...         res.append(x + y)
...
>>> res
[10, 20, 30, 11, 21, 31, 12, 22, 32]
```

## The iteration protocol

The *iteration protocol* defines a set of objects and methods used by all *iteration contexts*—including comprehensions, `for` loop statements, and built-in functions such as `map()` and `filter()`—to automatically step through items in collections or results produced on demand. Iteration works as follows:

- Iteration contexts operate on an *iterable*—an object with an `__iter__()` method.

- When called, the iterable's `__iter__()` method returns an *iterator*—an object with a `__next__()` method (possibly the same object).
- When called, the iterator's `__next__()` method returns the next item in the iteration or raises a `StopIteration` exception to end the iteration.

In addition, the `iter(X)` built-in function invokes an iterable's `X.__iter__()` method, and the `next(I)` built-in function calls an iterator's `I.__next__()` method, both to simplify manual iteration loops and as a portability layer. Some tools, such as the `map()` built-in and the *generator expression*, are both iteration context (for their subject) and iterable object (for their results); see prior and next sections.

Classes can provide an `__iter__()` method to intercept the `iter(X)` built-in operation; if defined, its result has a `__next__()` method used to step through results in iteration contexts. If no `__iter__()` is defined, the `__getitem__()` indexing method is used as a fallback to iterate until `IndexError`.

In *Python 2.X*, the `I.__next__()` iterator objects' method is named `I.next()`, but iteration works the same otherwise. The `next(I)` built-in function calls the `I.next()` method in 2.6 and 2.7 instead of `I.__next__()`, making it useful for both 3.X compatibility in 2.X, and 2.X compatibility in 3.X.

### Generator expressions

As of Python 2.4, generator expressions achieve effects similar to list comprehensions, without generating a physical list to hold all results. Generator expressions define a set of results, but do not materialize the entire list, to save memory; instead, they create a *generator object* that will return elements one by one in iteration contexts by automatically supporting the *iteration protocol* of the prior section. For example:

```
ords = (ord(x) for x in aString if x not in skipStr)
for o in ords:
    ...
```

Generator expressions are comprehensions coded inside parentheses rather than square brackets, but otherwise support all list comprehension syntax. The parentheses used for a function with a single argument suffice when creating an iterable to be passed to a function:

```
sum(ord(x) for x in aString)
```

Generator expression loop variables (e.g., x, in the prior example) are not accessible outside the generator expression in either Python 2.X or 3.X. In 2.X, list comprehensions leave the loop variable assigned to its last value, but all other comprehensions localize the variable to the expression; in Python 3.X, loop variables are localized to the expression in all comprehension forms.

To step through results outside iteration contexts such as `for` loops, use either the iteration protocol's *`I`*`.__next__()` method in 3.X, its *`I`*`.next()` method in Python 2.X, or the `next(`*`I`*`)` built-in function in either Python 2.X or 3.X, which calls the appropriate method portably. When required, use the `list()` call to produce all (remaining) results all at once (because generators are their own iterators, calling their `__iter__()` is harmless but not required):

```
>>> squares = (x ** 2 for x in range(5))
>>> squares
<generator object <genexpr> at 0x027C1AF8>

>>> iter(squares) is squares # __iter__() optional
True
>>> squares.__next__()       # Method (.next in 2.X)
0
>>> next(squares)            # Built-in (3.X, 2.6+)
1
>>> list(squares)            # Till StopIteration
[4, 9, 16]
```

See "The iteration protocol" for more on the mechanism used by generator expressions, and "The yield Statement" for the related *generator function*, which also creates a generator object.

### Other comprehension expressions

See also dictionary and set comprehensions elsewhere in this book (sections "Dictionaries" and "Sets"). These are similar expressions that produce dictionaries and sets all at once; they support syntax identical to list comprehensions and generator expressions, but are coded within {}, and dictionary comprehensions begin with a *key*:*value* expression pair:

```
>>> [x * x for x in range(10)]      # List comp
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

>>> (x * x for x in range(10))      # Generator expr
<generator object <genexpr> at 0x009E7328>

>>> {x * x for x in range(10)}      # Set: 3.X, 2.7
{0, 1, 4, 81, 64, 9, 16, 49, 25, 36}

>>> {x: x * x for x in range(10)}   # Dict: 3.X, 2.7
{0: 0, 1: 1, 2: 4, 3: 9, 4: 16, 5: 25, 6: 36, 7: 49,
8: 64, 9: 81}
```

## Dictionaries

Dictionaries are *mutable* (changeable) *mappings* of object references accessed by *key* (not position). They are unordered tables that map keys to values, implemented internally as dynamically expandable hash tables. Dictionaries differ substantially in Python 3.X:

- In *Python 2.X*, the `keys()`/`values()`/`items()` methods return lists; there is a `has_key()` lookup method; there are distinct iterable methods `iterkeys()`/`itervalues()`/`iteritems()`; and dictionaries may be compared directly. As of Python 2.7, 3.X's dictionary comprehensions are available as a back-port, and 3.X-style views are supported with methods `viewkeys()`/`viewvalues()`/`viewitems()`.
- In *Python 3.X*, the `keys()`/`values()`/`items()` methods return iterable *view* objects instead of lists; `has_key()` is removed in favor of `in` expressions; Python 2.X iterable

methods are removed in favor of *view* object iteration; dictionaries cannot be compared directly, but their `sorted(D.items())` can; and there is a new dictionary comprehension expression.

- Python 3.X *view* objects produce results on demand, retain the original order in the dictionary, reflect future dictionary changes, and may support *set* operations. Key views are always set-like, value views never are, and item views are if all their items are unique and hashable (immutable). See "Sets" for set expressions that may be applied to some views. Pass views to the `list()` call to force generation of all their results at once (e.g., for display, or to apply the list's `L.sort()`).

## Literals and creation

Dictionary literals are written as comma-separated series of *`key`*`:`*`value`* pairs inside curly braces, the `dict()` built-in supports other creation patterns, and dictionary comprehensions employ iteration in Python 3.X and 2.7. Assigning to new keys generates new entries.

Any *immutable* object can be a dictionary key (e.g., string, number, tuple), and class instances can be keys if they inherit hashing protocol methods (see `__hash__` in "Operator Overloading Methods"). Tuple keys support compound values (e.g., `adict[(M,D,Y)]`, with parentheses optional):

`{}`
: An empty dictionary (not a set).

`{'spam': 2, 'eggs': 3}`
: A two-item dictionary: keys `'spam'` and `'eggs'`, values `2` and `3`.

`D = {'info': {42: 1, type(''): 2}, 'spam': []}`
: Nested dictionaries: `D['info'][42]` fetches `1`.

`D = dict(name='Bob', age=45, job=('mgr', 'dev'))`
: Creates a dictionary by passing keyword arguments to the type constructor.

`D = dict(zip('abc', [1, 2, 3]))`
: Creates a dictionary by passing key/value tuple pairs to the type constructor.

`D = dict([['a', 1], ['b', 2], ['c', 3]])`
: Same effect as prior line: accepts any iterable of keys and values.

`D = {c.upper(): ord(c) for c in 'spam'}`
: Dictionary comprehension expression (in Python 3.X and 2.7). See "List comprehension expressions" for full syntax.

## Operations

Operations comprise all *mapping operations* (see Table 5), plus the following dictionary-specific *methods*, in all of which `D` stands for any dictionary object:

`D.keys()`
: All keys in `D`. In Python 2.X, this returns a list. In Python 3.X, it returns an iterable view object described earlier. `for K in D` also supports keys iteration implicitly.

`D.values()`
: All stored values in `D`. In Python 2.X, this returns a list. In Python 3.X, it returns an iterable view object described earlier.

`D.items()`
: Tuple pairs (`key, value`), one for each entry in `D`. In Python 2.X, this returns a list. In Python 3.X, it returns an iterable view object described earlier.

`D.clear()`
: Removes all items from `D`.

`D.copy()`
: Returns a shallow (top-level) copy of `D`.

`D.update(D2)`
: Merges all of *D2*'s entries into *D*, in-place, similar to `for (k, v) in D2.items(): D[k] = v`. In Python 2.4 and later, also accepts an iterable of key/value pairs, as well as keyword arguments (e.g., `D.update(k1=v1, k2=v2)`).

`D.get(K [, default])`
: Similar to `D[K]` for key *K*, but returns *default* (or `None` if no *default*) instead of raising an exception when *K* is not found in *D*.

`D.setdefault(K, [, default])`
: Same as `D.get(K, default)`, but also assigns key *K* to *default* if it is not found in *D*.

`D.popitem()`
: Removes and returns an arbitrary `(key, value)` tuple pair.

`D.pop(K [, default])`
: If key *K* in *D*, returns `D[K]` and removes *K*; else, returns *default* if given, or raises `KeyError` if no default.

`dict.fromkeys(I [, value])`
: Creates a new dictionary with keys from iterable *I* and values each set to *value* (default `None`). Callable on an instance *D* or type name `dict`.

The following methods are available in *Python 2.X* only:

`D.has_key(K)`
: Returns `True` if *D* has a key *K*, or `False` otherwise. In Python 2.X only, this method is equivalent to *K* `in` *D*, but is not generally recommended, as it is removed in Python 3.X.

`D.iteritems()`, `D.iterkeys()`, `D.itervalues()`
: Return iterables over key/value pairs, keys only, or values only. In Python 3.X, these are removed because `items()`, `keys()`, and `values()` return iterable view objects.

`D.viewitems()`, `D.viewkeys()`, `D.viewvalues()`
: Available as of 2.7, these return iterable view objects over key/value pairs, keys only, or values only, to emulate the view objects returned by 3.X's `items()`, `keys()`, and `values()`.

The following operations are described in Table 5, but relate to preceding methods:

*K* `in` *D*
: Returns `True` if *D* has key *K*, or `False` otherwise. Replaces `has_key()` in Python 3.X.

`for` *K* `in` *D*
: Iterates over keys *K* in *D* (all iteration contexts). Dictionary supports direct iteration: `for` *K* `in` *D* is similar to `for` *K* `in` *D*`.keys()`. The former uses the dictionary object's keys iterator. In Python 2.X, `keys()` returns a new list that incurs a slight overhead. In Python 3.X, `keys()` returns an iterable view object instead of a physically stored list, making both forms equivalent.

## Tuples

Tuples are *immutable* (unchangeable) *sequences* of object references accessed by *offset* (position).

### Literals and creation

Tuple literals are written as comma-separated series of values enclosed in parentheses. The enclosing parentheses can sometimes be omitted (e.g., in `for` loop headers and = assignments):

`()`
: An empty tuple.

`(0,)`
: A one-item tuple (not a simple expression).

`(0, 1, 2, 3)`
: A four-item tuple.

`0, 1, 2, 3`
: Another four-item tuple (same as prior line); not valid where comma or parentheses are otherwise significant (e.g., function arguments, 2.X prints).

`T = ('spam', (42, 'eggs'))`
: Nested tuples: `T[1][1]` fetches `'eggs'`.

`T = tuple('spam')`
: Creates a tuple of all items in any iterable, by calling the type constructor function.

### Operations

All *sequence operations* (see Table 3), plus the following tuple-specific *methods* in Python 2.6, 3.0, and later in both lines:

`T.index(X [, i [, j]])`
: Returns the index of the first occurrence of object `X` in tuple `T`; raises an exception if not found. This is a search method. If `i` and possibly `j` are passed, it returns the smallest `k` such that `T[k] == X` and `i <= k < j`, where `j` defaults to `len(T)`.

`T.count(X)`
: Returns the number of occurrences of `X` in tuple T.

## Files

The built-in `open()` function creates a *file object*, the most common interface to external files. File objects export the data transfer methods in the following sections, where file content is represented as Python strings. This is a partial list: see Python manuals for lesser-used calls and attributes.

In Python 2.X only, the name `file()` can be used as a synonym for `open()` when creating a file object, but `open()` is the generally recommended spelling. In Python 3.X, `file()` is no longer available. (The `io` module's classes are used for file customization.)

See the `open()` function in "Built-in Functions" for more complete file-creation details. See also "Unicode Strings" for the

distinction between text and binary files and their corresponding implied string type differences for content in Python 3.X.

Related file-like tools covered later in this book: see the `dbm`, `shelve`, and `pickle` modules in "Object Persistence Modules"; the `os` module file descriptor-based file functions and the `os.path` directory path tools in "The os System Module"; JSON file storage in "The json Module"; and SQL database usage in "Python SQL Database API".

See also Python's manuals for *`socketobj`*`.makefile()` to convert a socket to a file-like object, and `io.StringIO(`*`str`*`)` and `io.BytesIO(`*`bytes`*`)` (`StringIO.StringIO(`*`str`*`)` in Python 2.X) to convert a string to a file-like object, compatible with APIs that expect the file object interface defined here.

## Input files

*`infile`*` = open(`*`filename`*`, 'r')`

Creates input file object, connected to the named external file. *`filename`* is normally a string (e.g., `'data.txt'`), and maps to the current working directory unless it includes a directory path prefix (e.g., `r'c:\dir\data.txt'`). Argument two gives file *mode*: `'r'` reads text, `'rb'` reads binary with no line-break translation. Mode is optional and defaults to `'r'`. Python 3.X's `open()` also accepts an optional Unicode encoding name in text mode; 2.X's `codecs.open()` has similar tools.

*`infile`*`.read()`

Reads entire file, returning its contents as a single string. In text mode (`'r'`), line-ends are translated to `'\n'` by default. In binary mode (`'rb'`), the result string can contain nonprintable characters (e.g., `'\0'`). In Python 3.X, text mode *decodes* Unicode text into a `str` string, and binary mode returns unaltered content in a `bytes` string.

*`infile`*`.read(`*`N`*`)`

Reads at most *`N`* more bytes (1 or more); empty at end-of-file.

*infile*.readline()
: Reads next line (through end-of-line marker); empty at end-of-file.

*infile*.readlines()
: Reads entire file into a list of line strings. See also the file object's line iterator alternative, discussed in the next list item.

for *line* in *infile*
: Uses the *line iterator* of file object *infile* to step through lines in the file automatically. Available in all iteration contexts, including for loops, map(), and comprehensions (e.g., [line.rstrip() for line in open('*filename*')]). The iteration for *line* in *infile* has an effect similar to for *line* in *infile*.readlines(), but the line iterator version fetches lines on demand instead of loading the entire file into memory, and so is more space-efficient.

## Output files

*outfile* = open(*filename*, 'w')
: Creates output file object, connected to external file named by *filename* (defined in the preceding section). Mode 'w' writes text, 'wb' writes binary data with no line-break translation. Python 3.X's open() also accepts an optional Unicode encoding name in text mode; 2.X's codecs.open() has similar tools.

*outfile*.write(*S*)
: Writes all content in string *S* onto file, with no formatting applied. In text mode, '\n' is translated to the platform-specific line-end marker sequence by default. In binary mode, the string can contain nonprintable bytes (e.g., use 'a\0b\0c' to write a string of five bytes, two of which are binary zero). In Python 3.X, text mode requires str Unicode strings and *encodes* them when written, and binary mode expects and writes bytes strings unaltered.

*outfile*.writelines(*I*)
: Writes all strings in iterable *I* onto file, not adding any line-end characters automatically.

## Any files

*file*.close()
: Manual close to free resources (although CPython currently auto-closes files if still open when they are garbage collected). See also the file object's context manager in "File context managers".

*file*.tell()
: Returns the file's current position.

*file*.seek(*offset* [, *whence*])
: Sets the current file position to *offset* for random access. *whence* can be 0 (offset from front), 1 (offset +/– from current position), or 2 (offset from end). *whence* defaults to 0.

*file*.isatty()
: Returns True if the file is connected to a tty-like (interactive) device, else False (may return 1 or 0 in older Python versions).

*file*.flush()
: Flushes the file's stdio buffer. Useful for buffered pipes, if another process (or human) is reading. Also useful for files created and read in the same process.

*file*.truncate([*size*])
: Truncates file to, at most, *size* bytes (or current position if no size is passed). Not available on all platforms.

*file*.fileno()
: Gets file number (file descriptor integer) for file. This roughly converts file objects to file descriptors that can be passed to tools in the os module. Hint: use os.fdopen() or 3.X's open() to convert a file descriptor to a file object.

### Other file attributes (some read-only)

*file*.closed
: True if file has been closed

*file*.mode
: Mode string (e.g., 'r') passed to open() function

*file*.name
: String name of corresponding external file

### File context managers

In standard Python (CPython), file objects normally close themselves when garbage collected if still open. Because of this, temporary files (e.g., open('name').read()) suffice and need not be closed explicitly, as the file object is immediately reclaimed and closed. Other Python implementations (e.g., Jython), however, may collect and close files less deterministically.

To guarantee closes after a block of code exits, regardless of whether the block raises an exception, use the try/finally statement and manual closes:

```
myfile = open(r'C:\misc\script', 'w')
try:
    ...use myfile...
finally:
    myfile.close()
```

Or use the with/as statement available in Python 3.X and 2.X (as of 2.6 and 3.0):

```
with open(r'C:\misc\script', 'w') as myfile:
    ...use myfile...
```

The first of these inserts a close call as a termination-time action. The latter employs file object *context managers*, which guarantee that a file is automatically closed when the enclosed code block exits. See the try and with statements in "Statements and Syntax" for further details.

### File usage notes

- Some file-open modes (e.g., `'r+'`) allow a file to be both input and output, and others (e.g., `'rb'`) specify binary-mode transfer to suppress line-end marker conversions (and Unicode encodings in Python 3.X). See `open()` in "Built-in Functions".
- File-transfer operations occur at the current file position, but `seek()` method calls reposition the file for random access.
- File transfers can be made *unbuffered*: see `open()` arguments in "Built-in Functions", and the `-u` command-line flag in "Python Command Options".
- Python 2.X also includes an `xreadlines()` file object method, which works the same as the file object's automatic line iterator, and has been removed in Python 3.X due to its redundancy.

## Sets

Sets are *mutable* (changeable) and unordered collections of *unique and immutable* objects. Sets support mathematical set operations such as union and intersection. They are not sequences (they are unordered), and not mappings (they do not map values to keys), but support iteration, and function much like value-less (or keys-only) dictionaries.

### Literals and creation

In Python 2.X and 3.X, sets may be created by calling the `set()` built-in function, passing it an iterable whose items become members of the resulting set. In Python 3.X and 2.7, sets may also be created by `{...}` set literal and set comprehension expression syntax, although `set()` is still used to make an empty set (`{}` is the empty dictionary), and to build sets from existing objects.

Sets are mutable, but items in a set must be immutable; the `frozenset()` built-in creates an immutable set, which can be nested within another set:

`set()`
: An empty set ({} is an empty dictionary).

`S = set('spam')`
: A four-item set: values `'s'`, `'p'`, `'a'`, `'m'` (accepts any iterable).

`S = {'s', 'p', 'a', 'm'}`
: A four-item set, same as prior line (in Python 3.X and 2.7).

`S = {ord(c) for c in 'spam'}`
: Sets comprehension expression (in Python 3.X and 2.7); see "List comprehension expressions" for full syntax.

`S = frozenset(range(-5, 5))`
: A frozen (immutable) set of 10 integers, –5...4.

## Operations

The following documents the most prominent set operations, where *S*, *S1*, and *S2* are any set. Most expression operators require two sets, but their method-based equivalents accept any *iterable*, denoted by *other* in the following (e.g., `{1, 2} | [2, 3]` fails, but `{1, 2}.union([2, 3])` works). This list is representative but not complete; see Python's Library Reference for an exhaustive list of set expressions and methods available:

*x* `in S`
: Membership: returns `True` if set *S* contains *x*.

*S1* `-` *S2*, *S1*`.difference(`*other*`)`
: Difference: new set containing items in *S1* that are not in *S2* (or *other*).

*S1* `|` *S2*, *S1*`.union(`*other*`)`
: Union: new set containing items in either *S1* or *S2* (or *other*) with no duplicates.

*S1* & *S2*, *S1*.intersection(*other*)
: Intersection: new set containing items in both *S1* and *S2* (or *other*).

*S1* <= *S2*, *S1*.issubset(*other*)
: Subset: tests whether every element in *S1* is also in *S2* (or *other*).

*S1* >= *S2*, *S1*.issuperset(*other*)
: Superset: tests whether every element in *S2* (or *other*) is also in *S1*.

*S1* < *S2*, *S1* > *S2*
: True subset and superset: also tests that *S1* and *S2* are not the same.

*S1* ^ *S2*, *S1*.symmetric_difference(*other*)
: Symmetric difference: new set with elements in either *S1* or *S2* (or *other*) but not both.

*S1* |= *S2*, *S1*.update(*other*)
: Updates (not for frozen sets): adds items in *S2* (or *other*) to *S1*.

*S*.add(*x*), *S*.remove(*x*), *S*.discard(*x*), *S*.pop(), *S*.clear()
: Updates (not for frozen sets): adds an item, removes an item by value, removes an item if present, removes and returns an arbitrary item, removes all items.

len(*S*)
: Length: numbers items in set.

for *x* in *S*
: Iteration: all iteration contexts.

*S*.copy()
: Makes a top-level (shallow) copy of *S*; same as set(*S*).

## Other Types and Conversions

Python's core built-in types also include *Booleans*—described next; None—a false placeholder object; NotImplemented—used by

operator overloading methods; `Ellipsis`—created by the `...` literal in 3.X; *types*—accessed with the `type()` built-in function, and always classes in Python 3.X; and *program-unit types*—including functions, modules, and classes (all runtime and first-class objects in Python).

## Boolean

The Boolean type, named `bool`, provides two predefined constants added to the built-in scope, named `True` and `False` (available since version 2.3). For most purposes, these constants can be treated as though they were preassigned to integers `1` and `0`, respectively (e.g., `True + 3` yields `4`). However, the `bool` type is a subclass of the integer type `int`, and customizes it to print instances differently. (`True` prints as "True", not "1", and may be used as a built-in mnemonic name in logical tests.)

## Type Conversions

Tables 10 and 11 list built-in tools for converting from one type to another. All of these make *new* objects (they are not in-place converters). Python 2.X also supports `long(S)` to-long and `` `X` `` to-string converters, both removed in Python 3.X. See also "Numbers" and "String formatting" for some of the tools listed in these tables.

*Table 10. Sequence converters*

| Converter | Converts from | Converts to |
|---|---|---|
| `list(X)`, `[n for n in X]`[a] | String, tuple, any iterable | List |
| `tuple(X)` | String, list, any iterable | Tuple |
| `''.join(X)` | Iterable of strings | String |

[a] The list comprehension form may (or may not) be slower than `list()`, and may not be best practice in this specific conversion context. In Python 2.X only, `map(None, X)` has the same effect as `list(X)` in this context, although this form of `map()` is removed in Python 3.X.

*Table 11. String/object converters*

| Converter | Converts from | Converts to |
|---|---|---|
| `eval(S)` | String | Any object having expression syntax |
| `int(S[, base])`,[a] `float(S)` | String or number | Integer, float |
| `repr(X)`, `str(X)` | Any Python object | String (`repr` is as-code, `str` is user-friendly) |
| `F%X`, `F.format(X)`, `format(X, [F])` | Objects with format codes | String |
| `hex(X)`, `oct(X)`, `bin(X)`, `str(X)` | Integer types | Hexadecimal, octal, binary, decimal digit strings |
| `ord(C)`, `chr(I)` | Character, integer code | Integer code, character |

[a] In version 2.2 and later, converter functions (e.g., `int()`, `float()`, `str()`) also serve as class constructors and can be subclassed. In Python 3.X, all types are classes, and all classes are instances of the `type` class.

# Statements and Syntax

This section describes the rules for syntax and variable names.

## Syntax Rules

The following are the general rules for writing Python programs:

*Control flow*
: Statements execute sequentially, one after another, unless control-flow statements are used to branch elsewhere in code (e.g., `if`, `while`, `for`, `raise`, calls, etc.).

*Blocks*
: A nested block is delimited by indenting all of its statements by the same amount, with any number of spaces or tabs used consistently. A nested block can also appear on the same line as its statement header (following the header's `:` character), if it consists of simple (noncompound) statements only.

As a rule of thumb, a given block should use all tabs *or* all spaces for indentation. Combinations of the two are formally analyzed by two rules: (*1*) a tab counts for enough spaces to move the column number to the next multiple of 8; and (*2*) additional inconsistency is detected by counting each tab as one space.

In *Python 2.X*, combinations of tabs and spaces are allowed, if they satisfy just rule 1; however, mixing tabs and spaces is discouraged, as it is error prone and degrades clarity, and `-t` or `-tt` options can be used to flag combinations considered inconsistent per rule 2 (see "Python Command-Line Usage"). In *Python 3.X*, combinations of tabs and spaces are still allowed if they are valid and consistent per *both* rules 1 and 2, but are otherwise always errors (the same as 2.X's `-tt` option).

For example, in both 3.X and 2.X, an outer block indented with 2 spaces, 1 tab, and 2 spaces (rule 1: 10, rule 2: 5) allows an inner block indented with 1 tab and 5 spaces (rule 1: 13, rule 2: 6). An inner block with 2 tabs and 1 space (rule 1: 17, rule 2: 3) works in 2.X by default (rule 1) but fails in 3.X (rule 2). Maintainable code should not generally rely on these subtle rules: use tabs XOR spaces.

*Statements*
: A statement ends at the end of a line, but can continue over multiple lines if a physical line ends with a `\`; an unclosed `()`, `[]`, or `{}` pair; or an unclosed, triple-quoted string. Multiple simple statements can appear on a single line if they are separated with a semicolon (`;`).

*Comments*
: Comments start with a `#` in any column (and not in a string constant) and span to the end of the line; they are ignored by the Python interpreter.

*Documentation strings*
: If a function, module file, or class begins with a string literal (possibly after `#` comments), it is stored in the object's

`__doc__` attribute. See `help()` in "Built-in Functions", and the `pydoc` module and script in the Python Library Reference, for automated extraction and display tools. Hint: as of Python 3.2, `python -m pydoc -b` launches *PyDoc*'s browser-based interface (use `-g` instead of `-b` in earlier releases for GUI mode).

*Whitespace*
: Generally significant only to the left of code, where indentation is used to group blocks. Blank lines and spaces are otherwise ignored and optional except as token separators and within string constants.

## Name Rules

This section contains the rules for user-defined names (i.e., *variables*) in programs.

### Name format

*Structure*
: User-defined names start with a letter or underscore (_), followed by any number of letters, digits, or underscores.

*Reserved words*
: User-defined names cannot be the same as any Python reserved word listed in Table 12.[3]

*Case sensitivity*
: User-defined names and reserved words are always case-sensitive: *SPAM*, *spam*, and *Spam* are different names.

*Unused tokens*
: Python does not use the characters `$` and `?` in its syntax, although they can appear in string constants and comments. Within strings, `$` is special in template substitution (see

3. But this rule may be neither absolute nor strict outside the CPython implementation. The Jython Java-based system, for example, may allow reserved words to be used as variables in some contexts.

"Template string substitution"), and `$` and `?` are special in pattern matching (see "The re Pattern-Matching Module").

*Creation*
: User-defined names are created by assignment but must exist when referenced (e.g., counters must be explicitly initialized to zero). See the sections "Atomic terms and dynamic typing" and "Namespace and Scope Rules".

*Table 12. Python 3.X reserved words*

| | | | | |
|---|---|---|---|---|
| `False` | `class` | `finally` | `is` | `return` |
| `None` | `continue` | `for` | `lambda` | `try` |
| `True` | `def` | `from` | `nonlocal` | `while` |
| `and` | `del` | `global` | `not` | `with` |
| `as` | `elif` | `if` | `or` | `yield` |
| `assert` | `else` | `import` | `pass` | |
| `break` | `except` | `in` | `raise` | |

**NOTE**

*In Python 2.X*, `print` and `exec` are both reserved words, as they take the form of statements, not built-in functions. Also in Python 2.X, `nonlocal`, `True`, and `False` are not reserved words; the first of these is unavailable, and the latter two are simply built-in names. `with` and `as` are reserved as of both 2.6 and 3.0, but not in earlier 2.X releases unless context managers are explicitly enabled. `yield` is reserved as of 2.3; it morphed from statement to expression later but is still a reserved word.

## Name conventions

- Names that begin and end with two underscores (for example, `__init__`) have a special meaning to the interpreter but are not reserved words.

- Names beginning with one underscore (e.g., `_X`) and assigned at the top level of a module are not copied out by `from...*` imports (see also the `__all__` module export names list in the sections "The from Statement" and "Pseudoprivate Attributes"). In other contexts, this is an informal convention for internal names.
- Names beginning but not ending with two underscores (e.g., `__X`) within a `class` statement are prefixed with the enclosing class's name (see "Pseudoprivate Attributes").
- The name that is just a single underscore (`_`) is used in the interactive interpreter (only) to store the result of the last evaluation.
- Built-in function and exception names (e.g., `open`, `SyntaxError`) are not reserved words. They live in the last-searched scope and can be reassigned to hide (a.k.a. *shadow*) the built-in meaning in the current scope (e.g., `open = myfunction`).
- Class names commonly begin with an uppercase letter (e.g., `MyClass`), and modules with a lowercase letter (e.g., `mymodule`).
- The first (leftmost) argument in a class method function is usually named `self`, by very strong convention.
- Module names are resolved according to a directory search path scan; names located earlier on the path can hide others of the same name, whether intended or not (see "The import Statement").

## Specific Statements

The following sections describe all Python statements. Each section lists the statement's syntax formats, followed by usage details. For compound statements, each appearance of a *suite* in a statement format stands for one or more other statements, possibly indented as a block under a header line. A suite must be indented

under a header if it contains another compound statement (`if`, `while`, etc.); otherwise, it can appear on the same line as the statement header. The following are both valid constructs:

```
if x < 42:
    print(x)
    while x: x = x - 1

if x < 42: print(x)
```

The following subsections give details common to both Python 3.X and 2.X; see also "Python 2.X Statements" at the end of this section for details unique to 2.X.

## The Assignment Statement

```
target = expression
target1 = target2 = expression
target1, target2 = expression1, expression2
target1 += expression

target1, target2,  ...  = same-length-iterable
(target1, target2, ...) = same-length-iterable
[target1, target2, ...] = same-length-iterable
target1, *target2, ...  = matching-length-iterable
```

All assignments store *references* to objects in targets. Assignment statements request assignment with the preceding explicit syntax formats, in which:

- *Expressions* produce objects.
- *Targets* can be simple names (*X*), qualified attributes (*X.attr*), or indexes and slices (*X*[*i*], *X*[*i*:*j*:*k*]).
- *Variables* in targets are not declared ahead of time, but must have been assigned before being used in an expression (see "Atomic terms and dynamic typing").

The first format listed above is *basic* assignment. The second format, *multiple-target* assignment, assigns the same expression result object to each target. The third format, *tuple* assignment,

pairs targets with expressions, left to right. The fourth format, *augmented* assignment, is shorthand for an operation plus an assignment (see the next section).

The last four formats are *sequence* assignment, and assign components of any sequence or other iterable to corresponding targets, from left to right. The sequence or iterable on the right can be any type, but must be the same length unless a single starred-name (`*X`) appears in the targets on the left, as in the last format. This last format, known as *extended sequence* assignment and available in Python 3.X only, allows the starred name to collect arbitrarily many items (see "Extended sequence assignment (3.X)").

Assignment also occurs *implicitly* in other contexts in Python (e.g., `for` loop variables and function argument passing), and some assignment statement formats apply elsewhere (e.g., sequences in `for`).

### Augmented assignment

A set of additional assignment statement formats, listed in Table 13, are available. Known as *augmented assignments*, these formats imply a binary expression plus an assignment. For instance, the following two formats are roughly equivalent:

```
X = X + Y
X += Y
```

However, the reference to target `X` in the second format needs to be evaluated only *once*, and *in-place* operations may be applied for mutables as an optimization (e.g., `list1 += list2` automatically calls `list1.extend(list2)`, instead of the slower concatenation operation implied by `+`). Classes can overload in-place assignments with method names that begin with an `i` (e.g., `__iadd__()` for `+=`, `__add__()` for `+`). The format `X //= Y` (floor division) was added as of version 2.2.

*Table 13. Augmented assignment statements*

| | | | |
|---|---|---|---|
| `X += Y` | `X &= Y` | `X -= Y` | `X \|= Y` |
| `X *= Y` | `X ^= Y` | `X /= Y` | `X >>= Y` |
| `X %= Y` | `X <<= Y` | `X **= Y` | `X //= Y` |

## Normal sequence assignment

In Python 2.X and 3.X, any sequence or other iterable of values may be assigned to any sequence of names, as long as the lengths are the same. This basic sequence assignment form works in most assignment contexts:

```
>>> a, b, c, d = [1, 2, 3, 4]
>>> a, d
(1, 4)

>>> for (a, b, c) in [[1, 2, 3], [4, 5, 6]]:
...     print(a, b, c)
...
1 2 3
4 5 6
```

## Extended sequence assignment (3.X)

In Python 3.X (only), sequence assignment is extended to allow collection of arbitrarily many items, by prefixing one variable in the assignment target with a star; when used, sequence lengths need not match, and the starred name collects all otherwise unmatched items in a new list:

```
>>> a, *b = [1, 2, 3, 4]
>>> a, b
(1, [2, 3, 4])

>>> a, *b, c = (1, 2, 3, 4)
>>> a, b, c
(1, [2, 3], 4)

>>> *a, b = 'spam'
>>> a, b
```

```
(['s', 'p', 'a'], 'm')

>>> for (a, *b) in [[1, 2, 3], [4, 5, 6]]:
...     print(a, b)
...
1 [2, 3]
4 [5, 6]
```

---

**NOTE**

*Python 3.5 or later star generalization?* In Python 3.3 and earlier, the special **X* and ***X* syntax forms can appear in three places: in *assignment statements*, where a **X* collects unmatched items in sequence assignments; in *function headers*, where the two forms collect unmatched positional and keyword arguments; and in *function calls*, where the two forms unpack iterables and dictionaries into individual items (arguments).

In Python 3.4, developers considered generalizing this star syntax to also be usable within *data structure literals*—where it would unpack collections into individual items, much like its original use in function calls. Specifically, the unpacking star syntax may be allowed to appear in *tuples*, *lists*, *sets*, *dictionaries*, and *comprehensions*. For example:

```
[x, *iter]             # unpack iter items: list
(x, *iter), {x, *iter} # same for tuple, set
{'x': 1, **dict}       # unpack dict items: dicts
[*iter for iter in x]  # unpack iter items: comps
```

This is in addition to its original three roles in assignment statements, and function headers and calls. Some current restrictions regarding use of the star syntax may also be lifted in the process. This proposed change was postponed until after 3.4 just before this edition was published and remains uncertain—indeed, it has been debated since 2008, won't be reconsidered until Python 3.5 or later, and may never appear at all—so check Python "What's New" documents for more details.

---

## The Expression Statement

```
expression
function([value, name=value, *name, **name...])
object.method([value, name=value, *name, **name...])
```

Any expression can appear as a statement (e.g., on a line by itself). Conversely, statements cannot appear in any other expression context (e.g., assignment statements have no result, and cannot be nested).

Expression statements are commonly used for calling functions and methods having no useful return value, and for interactive-mode printing. Expression statements are also the most common coding for `yield` expressions and Python 3.X `print()` built-in function calls, although both are documented as specific statements in this book.

### Call syntax

In function and method calls, actual arguments are separated by commas and are normally matched to arguments in function `def` headers by position. Calls can optionally list specific argument names in functions to receive passed values by using the *`name=value`* keyword argument syntax. Keyword arguments match by name instead of position.

### Arbitrary arguments call syntax

Special star syntax can also be used in function and method call argument lists to *unpack* collections into arbitrarily many individual arguments. If *`pargs`* and *`kargs`* are an iterable and a dictionary, respectively:

```
f(*pargs, **kargs)
```

Then this format calls function `f` with *positional* arguments from iterable *`pargs`*, and *keyword* arguments from dictionary *`kargs`*. For instance:

```
>>> def f(a, b, c, d): print(a, b, c, d)
...
```

```
>>> f(*[1, 2], **dict(c=3, d=4))
1 2 3 4
```

This syntax is intended to be symmetric with function header arbitrary-argument syntax such as `def f(*pargs, **kargs)`, which *collects* unmatched arguments. In calls, starred items are unpacked into individual arguments, and may be combined with other positional and keyword arguments in accordance with ordering rules (e.g., `g(1, 2, foo=3, bar=4, *pargs, **kargs)`).

In Python 2.X, the `apply()` built-in function achieves a similar effect, but is removed in Python 3.X:

```
apply(f, pargs, kargs)
```

See also "The def Statement", including Table 15, for more call syntax details.

## The print Statement

In Python 3.X, printing text to the standard output stream takes the form of a built-in function call, which is commonly coded as an expression statement (e.g., on a line by itself). Its call signature is as follows:

```
print([value [, value]*]
      [, sep=str] [, end=str]
      [, file=object] [, flush=bool])
```

Each *value* is an expression that produces an object, whose `str()` string is to be printed. This call is configured by its four optional keyword-only arguments (defaults apply if omitted or passed `None`):

`sep`
: A string to place between values (default is space: `' '`).

`end`
: A string to place at the end of the text printed (default is newline: `'\n'`).

`file`
: The file-like object to which text is written (default is standard output: `sys.stdout`).

`flush`
: Passed true/false, to enable/disable forced output stream flush (as of Python 3.3; default is `False`).

Pass empty or custom strings to `sep` and `end` to suppress or override space separators and line feeds. Pass a file or file-like object to `file` to redirect output in your script (see also "Files"):

```
>>> print(2 ** 32, 'spam')
4294967296 spam

>>> print(2 ** 32, 'spam', sep='')
4294967296spam

>>> print(2 ** 32, 'spam', end=' '); print(1, 2, 3)
4294967296 spam 1 2 3

>>> print(2 ** 32, 'spam', sep='',
...                file=open('out', 'w'))
>>> open('out').read()
'4294967296spam\n'
```

Because by default `print` operations simply call the `write()` method of the object currently referenced by `sys.stdout`, the following is equivalent to `print(X)`:

```
import sys
sys.stdout.write(str(X) + '\n')
```

To redirect `print` text to files or class objects, either pass any object with a `write()` method to the `file` keyword argument as shown earlier, or reassign `sys.stdout` to any such object (see also "Files"):

```
sys.stdout = open('log', 'a')  # Object with write()
print('Warning-bad spam!')     # To object's write()
```

Because `sys.stdout` can be reassigned, the `file` keyword argument is not strictly needed; however, it can often avoid both

explicit `write()` method calls, and saving and restoring the original `sys.stdout` value around a redirected `print` operation when the original stream is still required. For more on the 3.X `print()`, see also "Built-in Functions".

### Python 2.X print statements

In Python 2.X, printing is a specific statement instead of a built-in function, of the following form:

```
print [value [, value]* [,]]
print >> file [, value [, value]* [,]]
```

The Python 2.X `print` statement displays the printable representation of each *`value`* on the standard output stream—the current setting of `sys.stdout`—and adds spaces between values. A trailing comma suppresses the line feed that is normally added at the end of a list, and is equivalent to using `end=' '` in Python 3.X's printing function:

```
>>> print 2 ** 32, 'spam'
4294967296 spam

>>> print 2 ** 32, 'spam',; print 1, 2, 3
4294967296 spam 1 2 3
```

The Python 2.X `print` statement can also name an open output file-like object to be the target of the printed text, instead of `sys.stdout`:

```
fileobj = open('log', 'a')
print >> fileobj, "Warning-bad spam!"
```

If the file object is `None`, `sys.stdout` is used. This Python 2.X `>>` syntax is equivalent to the `file=`*`F`* keyword argument in Python 3.X. There is no equivalent to `sep=`*`S`* in Python 2.X's statement, although lines can be preformatted and printed as a single item.

Parentheses work in 2.X's `print`, but create tuples for multiple items. To use the Python 3.X printing function in Python 2.X, run the following in an interactive session or at the top of a script—this can be used both in *2.X* (for 3.X forward compatibility), and in *3.X* (for 2.X backward compatibility):

```
from __future__ import print_function
```

## The if Statement

```
if test:
    suite
[elif test:
    suite]*
[else:
    suite]
```

The `if` statement selects from among one or more actions (statement blocks). It runs the suite associated with the first `if` or `elif` test that is true, or the `else` suite if all tests are false. The `elif` and `else` parts are optional.

## The while Statement

```
while test:
    suite
[else:
    suite]
```

The `while` loop is a general loop that keeps running the first suite while the test at the top is true. It runs the optional `else` suite once on exit if the loop ends without running into a `break` statement in the first suite.

## The for Statement

```
for target in iterable:
    suite
[else:
    suite]
```

The `for` loop is a sequence (or other iterable) iteration that assigns items in *`iterable`* to *`target`* and runs the first suite for each. The `for` statement runs the optional `else` suite once on exit if the loop ends without running into a `break` statement in the first suite. *`target`* can be anything that can appear on the left side of an `=` assignment statement (e.g., `for (x, y) in tuplelist`).

Since Python 2.2, this works by first trying to obtain an *iterator* object *I* with `iter(`*`iterable`*`)` and then calling that object's *I*`.__next__()` method repeatedly until `StopIteration` is raised (*I*`.__next__()` is named *I*`.next()` in Python 2.X). If no iterator object can be obtained (e.g., no `__iter__` method is defined), this works instead by repeatedly indexing *`iterable`* at successively higher offsets until an `IndexError` is raised.

Iteration occurs in multiple contexts in Python, including `for` loop statements, comprehensions, and `map()`. See "The iteration protocol" in the coverage of lists for more on the mechanism used by the `for` loop and all other iteration contexts.

## The pass Statement

```
pass
```

This is a do-nothing placeholder statement, and is used when syntactically necessary (e.g., for stubbed-out function bodies). In Python 3.X only, ellipses (literally, `...`) can achieve similar effects.

## The break Statement

```
break
```

This immediately exits the closest (innermost) enclosing `while` or `for` loop statement, skipping its associated `else` (if any). Hint: `raise` and `try` statements can be used to exit multiple loop levels.

## The continue Statement

```
continue
```

This immediately goes to the top of the closest enclosing `while` or `for` loop statement; it resumes in the loop's header line.

## The del Statement

```
del name
del name[i]
del name[i:j:k]
del name.attribute
```

The `del` statement deletes variables, items, keys, slices, and attributes. In the first form, *`name`* is a variable name taken literally. In the last three forms, *`name`* can be any expression that evaluates to the subject object (with parentheses if required for priority). For instance: `del a.b()[1].c.d`.

This statement is primarily for data structures, not memory management. It also removes a reference to formerly referenced objects, which may cause them to be *garbage collected* (reclaimed) if not referenced elsewhere. However, garbage collection is automatic, and need not normally be forced with `del`.

## The def Statement

```
[decoration]
def name([arg,... arg=value,... *arg, **arg]):
    suite
```

The `def` statement makes new functions, which may also serve as methods in classes. It creates a function object and assigns it to variable *`name`*. Each call to a function object generates a new, local scope, where assigned names are local to the function call by default (unless declared `global`, or `nonlocal` in 3.X). For more on scopes, see "Namespace and Scope Rules".

Arguments are passed by assignment; in a `def` header, they can be defined by any of the four formats in Table 14. The argument forms in Table 14 can also be used in a function call, where they are interpreted as shown in Table 15 (see "The Expression Statement" for more on function call syntax).

*Table 14. Argument formats in definitions*

| Argument format | Interpretation |
|---|---|
| *`name`* | Matched by name or position |
| *`name=value`* | Default value if *`name`* is not passed |
| `*`*`name`* | Collects extra positional arguments as new tuple *`name`* |
| `**`*`name`* | Collects extra keyword arguments as a new dictionary *`name`* |

| Argument format | Interpretation |
| --- | --- |
| **other, name[=value]* | Python 3.X keyword-only arguments after * |
| **, name[=value]* | Same as prior line (when no * otherwise) |

*Table 15. Argument formats in calls*

| Argument format | Interpretation |
| --- | --- |
| *value* | Positional argument |
| *name=value* | Keyword (match by name) argument |
| **iterable* | Unpacks sequence or other iterable of positional arguments |
| ***dictionary* | Unpacks dictionary of keyword arguments |

## Python 3.X keyword-only arguments

Python 3.X (only) generalizes function definition to allow keyword-only arguments, which must be passed by keyword, and are required if not coded with defaults. Keyword-only arguments are coded after the *, which may appear without a name if there are keyword-only arguments but not arbitrary positionals:

```
>>> def f(a, *b, c): print(a, b, c)  # Required kw c
...
>>> f(1, 2, c=3)
1 (2,) 3

>>> def f(a, *, c=None): print(a, c) # Optional kw c
...
>>> f(1)
1 None
>>> f(1, c='spam')
1 spam
```

## Python 3.X function annotations

Python 3.X (only) also generalizes function definition to allow arguments and return values to be annotated with object values for use in extensions. Annotations are coded as *:value* after the argument name and before a default, and as *->value* after the

argument list. They are collected into an `__annotations__` attribute of the function, but are not otherwise treated as special by Python itself:

```
>>> def f(a:99, b:'spam'=None) -> float:
...     print(a, b)
...
>>> f(88)
88 None
>>> f.__annotations__
{'a': 99, 'b': 'spam', 'return': <class 'float'>}
```

## lambda expressions

Functions can also be created with the `lambda` expression form, which creates a new function object and returns it to be called later, instead of assigning it to a name:

```
lambda arg, arg,...: expression
```

In `lambda`, each *`arg`* is as in `def` (Table 14), and *`expression`* is the implied return value of later calls; code in *`expression`* is effectively deferred until calls:

```
>>> L = lambda a, b=2, *c, **d: [a, b, c, d]
>>> L(1, 2, 3, 4, x=1, y=2)
[1, 2, (3, 4), {'y': 2, 'x': 1}]
```

Because `lambda` is an expression, not a statement, it can be used in places that a `def` cannot (e.g., within a dictionary literal expression or an argument list of a function call). Because `lambda` computes a single expression instead of running statements, it is not intended for complex functions (use `def`).

## Function defaults and attributes

Mutable default argument values are evaluated once at `def` statement time, not on each call, and so can retain state between calls. However, some consider this behavior to be a caveat, and classes and enclosing scope references are often better state-retention tools; use `None` defaults for mutable and explicit tests to avoid unwanted changes, as shown in the following's comments:

```
>>> def grow(a, b=[]):    # def grow(a, b=None):
...     b.append(a)       #     if b == None: b = []
...     print(b)          #     ...
...
>>> grow(1); grow(2)
[1]
[1, 2]
```

Both Python 2.X and 3.X also support attachment of arbitrary *attributes* to functions, as another form of state retention (although attributes support only per-function-object state, which is per-call only if each call generates a new function object):

```
>>> grow.food = 'spam'
>>> grow.food
'spam'
```

## Function and method decorators

As of Python 2.4, function definitions can be preceded by a declaration syntax that describes the function that follows. Known as *decorators* and coded with an `@` character, these declarations provide explicit syntax for functional techniques. The function decorator syntax:

```
@decorator
def F():
    ...
```

is equivalent to this manual name rebinding:

```
def F():
    ...
F = decorator(F)
```

The effect is to rebind the function name to the result of passing the function through the *`decorator`* callable. Function decorators may be used to manage functions, or later calls made to them (by using proxy objects). Decorators may be applied to any function definition, including methods inside a class:

```
class C:
    @decorator
    def M():            # Same as M = decorator(M)
        ...
```

More generally, the following nested decoration:

```
@A
@B
@C
def f(): ...
```

is equivalent to the following nondecorator code:

```
def f(): ...
f = A(B(C(f)))
```

Decorators may also take argument lists:

```
@spam(1, 2, 3)
def f(): ...
```

In this case, `spam` must be a function returning a function, and is known as a *factory function*; its result is used as the actual decorator, and may retain argument state as needed. Decorators must appear on the line preceding a function definition, not the same line (e.g., `@A def f(): ...` on a single line is illegal).

Because they accept and return callables, some built-in functions, including `property()`, `staticmethod()`, and `classmethod()`, may be used as function decorators (see "Built-in Functions"). Decorator syntax is also supported for *classes* in Python 2.6 and 3.0, and later in both lines; see "The class Statement".

## The return Statement

```
return [expression]
```

The `return` statement exits the enclosing function and returns an *`expression`* value as the result of the call to the function. If *`expression`* is omitted, it defaults to `None`, which is also the default return value for functions that exit without a `return`. Hint: return a tuple for multiple-value function results. See also "The yield

Statement" for special semantics of `return` when used in a generator function.

## The yield Statement

```
yield expression          # All Pythons
yield from iterable       # 3.3 and later
```

The `yield` expression in 2.X and 3.X defines a *generator function*, which produces results on demand. Functions containing a `yield` are compiled specially; when called, they create and return a *generator object*—an iterable that automatically supports the *iteration protocol* to provide results in iteration contexts.

Commonly coded as an expression statement (e.g., on a line by itself), `yield` suspends function state and returns an *`expression`* value. On the next iteration, the function's prior location and variable state are restored, and control resumes immediately after the `yield` statement.

Use a `return` statement to end the iteration or simply fall off the end of the function. A generator function `return` must give no return value prior to 3.3, but may provide one in 3.3 and later that is retained as an exception object attribute (see "Generator function changes in Python 3.3"):

```
def generateSquares(N):
    for i in range(N):
        yield i ** 2

>>> G =  generateSquares(5) # Has __init__, __next__
>>> list(G)                 # Generate results now
[0, 1, 4, 9, 16]
```

When used as an expression (e.g., `A = yield X`), `yield` returns the object passed to the generator's `send()` method at the caller, and must be enclosed in parenthesis unless it is the only item on the right of `=` (e.g., `A = (yield X) + 42`). In this mode, values are sent to a generator by calling `send(`*`value`*`)`; the generator is resumed, and the `yield` expression returns *`value`*. If the regular `__next__()` method or `next()` built-in function is called to advance, `yield` returns `None`.

Generator functions also have a `throw(type)` method to raise an exception inside the generator at the latest `yield`, and a `close()` method that raises a new `GeneratorExit` exception inside the generator to terminate the iteration. `yield` is standard as of version 2.3 and later; generator `send()`, `throw()`, and `close()` methods are available as of Python 2.5.

A class `__iter__()` method containing a `yield` returns a generator with an automatically created `__next__()`. See "The iteration protocol" in the coverage of lists for the mechanism used by generator functions, and "Generator expressions" for a related tool which also creates a generator object.

### Generator function changes in Python 3.3

As of 3.3, Python 3.X (only) supports a `from` clause in this statement, which in basic usage is similar to a yielding `for` loop that steps through items in an *`iterable`*; in more advanced roles, this extension allows subgenerators to receive sent and thrown values directly from the higher calling scope:

```
for i in range(N): yield i    # All Pythons
yield from range(N)           # 3.3 and later option
```

Also as of 3.3, if a generator function stops iteration and exits with an explicit `return` statement, any value given in the `return` is made available as the `value` attribute of the implicitly created and raised `StopIteration` instance object. This value is ignored by automatic iterations, but may be queried by manual iterations or other code that accesses the exception (see "Built-in Exceptions"). In Python 2.X, and in 3.X prior to 3.3, a `return` with a value in a generator function is treated as a syntax error.

## The global Statement

```
global name [, name]*
```

The `global` statement is a namespace declaration: when used inside a class or function definition statement, it causes all appearances of *`name`* in that context to be treated as references to a global

(module-level) variable of that name—whether `name` is assigned or not, and whether `name` already exists or not.

This statement allows globals to be created or changed within a function or class. Because of Python's scope rules, you need to declare only global names that are *assigned*; undeclared names are made local if assigned, but global references are automatically located in the enclosing module. See also "Namespace and Scope Rules".

## The nonlocal Statement

```
nonlocal name [, name]*
```

Available in Python 3.X only.

The `nonlocal` statement is a namespace declaration: when used inside a nested function, it causes all appearances of *`name`* in that context to be treated as references to a local variable of that name in an enclosing function's scope—whether `name` is assigned or not.

`name` must exist in an enclosing function; this statement allows it to be changed by a nested function. Because of Python's scope rules, you need to declare only nonlocal names that are *assigned*; undeclared names are made local if assigned, but nonlocal references are automatically located in enclosing functions. See also "Namespace and Scope Rules".

## The import Statement

```
import [package.]* module [as name]
          [, [package.]* module [as name]]*
```

The `import` statement provides module access: it imports a module as a whole. Modules in turn contain names fetched by qualification: *`module.attribute`*. Assignments at the top level of a Python file create module object attributes. The optional `as` clause assigns a variable *`name`* to the imported module object and removes the original *`module`* name (useful to provide shorter synonyms for long module names or package paths), and optional

*package* prefixes denote package directory paths (described in the next section).

*module* names the target *module*, which is usually a Python source-code or compiled byte-code file. The *module* is given without its filename extension (e.g., *.py*), and must generally be located in a directory on the module search path unless nested in a *package* path.

For the leftmost *module* or *package* components in absolute import paths, the *module search path* is `sys.path`—a directory name list initialized from the program's top-level directory, `PYTHONPATH` settings, `.pth` path file contents, and Python defaults. Modules may instead be located in a single package directory for nested package components (see "Package imports") and relative imports in `from` statements (see "Package relative import syntax"), and search paths may span directories arbitrarily for namespace packages as of Python 3.3 (see "Python 3.3 namespace packages").

The first time a module is imported by a program, its source-code file is compiled to *byte code* if needed (and saved in a *.pyc* file if possible), and then executed from top to bottom to generate module object attributes by assignment. In Python 2.X and 3.1 and earlier, byte-code files are saved in the source-code file's directory with the same base name (e.g., *module.pyc*). In Python 3.2 and later, byte code is saved in a *__pycache__* subdirectory of the source-code file's directory, with a version-identifying base name (e.g., *module.cpython-33.pyc*).

Later imports use the already-imported module, but `imp.reload()` (`reload()` in 2.X) forces reimports of already-loaded modules. To import by string name, see `__import__()` used by `import` in "Built-in Functions" and the standard library's `importlib.import_module(`*modname*`)`.

In standard CPython, imports may also load compiled C and C++ extensions, with attributes corresponding to external language names. In other implementations, imports may also name

other language's class libraries (e.g., Jython may generate a Python module wrapper that interfaces with a Java library).

### Package imports

If used, the *package* prefix names give enclosing directory names, and module dotted paths reflect directory hierarchies. An import of the form `import` *`dir1.dir2.mod`* generally loads the module file at directory path *dir1/dir2/mod.py*, where *dir1* must be contained by a directory listed on the module search path (`sys.path` for absolute imports) and *dir2* is located in *dir1* (not on `sys.path`).

In regular packages, each directory listed in an import statement must have a (possibly empty) *__init__.py* file that serves as the directory level's module namespace. This file is run on the first import through the directory, and all names assigned in *__init__.py* files become attributes of the directory's module object. Directory packages can resolve same-name conflicts caused by the linear nature of `PYTHONPATH`.

See also "Package relative import syntax" for more on intra-package references in `from` statements, and "Python 3.3 namespace packages" for an alternative package type which requires no *__init__.py* file.

### Python 3.3 namespace packages

As of Python 3.3, the import operation is extended to recognize *namespace packages*—module packages that are the virtual concatenation of one or more directories nested in module search path entries.

Namespace packages do not (and cannot) contain an *__init__.py* file. They serve as a fallback option and extension to regular modules and packages, recognized only if a name is not located otherwise but matches one or more directories found during the search path scan. This feature is activated by both the `import` and `from` statements.

### Import algorithm

With the addition of namespaces packages, imports follow their usual initial steps as before (e.g., checking for already-imported modules and byte-code files), but the search for a module is extended as follows.

During imports, Python iterates over each directory in the *module search path*—defined by `sys.path` for the leftmost components of absolute imports, and by a package's location for relative imports and components nested in package paths. As of 3.3, while looking for an imported module or package named *spam*, for each *directory* in the module search path, Python tests for matching criteria in this order:

1. If *directory\spam__init__.py* is found, a *regular package* is imported and returned.
2. If *directory\spam.{py, pyc, or other module extension}* is found, a simple *module* is imported and returned.
3. If *directory\spam* is found and is a directory, it is recorded and the scan continues with the next directory in the search path.
4. If none of the above was found, the scan continues with the next directory in the search path.

If the search path scan completes without returning a module or package by steps *1* or *2*, and at least one *directory* was recorded by step *3*, then a *namespace package* is immediately created. The new namespace package has a `__path__` attribute set to an iterable of the directory path strings that were found and recorded during the scan by step *3*, but does not have a `__file__`.

The `__path__` attribute is used in later accesses to search all package components whenever further nested items are requested, much like the sole directory of a regular package. It serves the same role for lower-level components that `sys.path` does at the top for the leftmost components of absolute import paths,

becoming the parent path for accessing lower items using the same four-step algorithm.

## The from Statement

```
from [package.]* module import
           [() name [as othername]
           [, name [as othername]]* [)]

from [package.]* module import *
```

The `from` statement imports a module just as in the `import` statement (see the preceding section), but also copies variable names from the module to be used without qualification: *`attribute`*. The second format (`from ... import *`) copies *all* names assigned at the top level of the module, except those with a single leading underscore or not listed in the module's `__all__` list-of-strings attribute (if defined).

If used, the `as` clause creates a name synonym as in the `import` statement, and works for any *`name`* component. If used, *`package`* import paths also work as in `import` (e.g., `from` *`dir1.dir2.mod`* `import` *`X`*) for both regular and 3.3 namespace packages, although the package path needs to be listed only once in the `from` itself (not at each attribute reference). As of Python 2.4, the names being imported from a module can be enclosed in parentheses to span multiple lines without backslashes (this is special-case syntax for `from` only).

In Python 3.X, the `from ... import *` form is invalid within a function or class, because it makes it impossible to classify name scopes at definition time. Due to scoping rules, the `*` format also generates warnings in 2.X as of version 2.2 if it appears nested in a function or class.

The `from` statement is also used to enable future (but still pending) language additions, with `from __future__ import` *`featurename`*. This format must appear only at the top of a module file (preceded only by a docstring or comments), or anytime during an interactive session.

### Package relative import syntax

In Python 3.X and 2.X, the `from` statement (but *not* `import`) may use leading dots in module names to specify intra-package module references—imports which are *relative* to the package directory in which the importing module resides only. Relative imports restrict the initial module search path to the package directory. Other imports are *absolute*, locating modules on `sys.path`. General syntax patterns:

```
from source import name [, name]*    # Abs: sys.path

from . import module [, module]*     # Rel: pkg only
from .source import name [, name]*   # Rel: pkg only

from .. import module [, module]*    # Parent in pkg
from ..source import name [, name]*  # Parent in pkg
```

In this `from` form, *`source`* may be a simple identifier or dot-separated package path, *`name`* and *`module`* are simple identifiers, and leading dots identify the import as package relative. The `as` renaming extension (not shown here) also works in this form as in normal `from` for both *`name`* and *`module`*.

Leading-dots syntax works in both Python 3.X and 2.X to make imports explicitly package relative. However, for imports *without* leading dots, the package's own directory is searched first in Python 2.X, but not in Python 3.X. To enable full Python 3.X package import semantics in Python 2.6 and later, use:

```
from __future__ import  absolute_import
```

Because they may support a broader range of use cases, absolute package import paths, relative to a directory on `sys.path`, are often preferred over both implicit package-relative imports in Python 2.X, and explicit package-relative import syntax in both Python 2.X and 3.X.

## The class Statement

```
[decoration]
class name [ ( super [, super]* [, metaclass=M] ) ]:
    suite
```

The `class` statement makes new class objects, which are factories for making instance objects. The new class object inherits from each listed *`super`* class in the order given, and is assigned to variable *`name`*. The `class` statement introduces a new local name scope, and all names assigned in the `class` statement generate class object attributes shared by all instances of the class.

Important class features include the following; for further class and OOP details, see also the sections "Object-Oriented Programming" and "Operator Overloading Methods":

- *Superclasses* (also known as base classes) from which a new class inherits attributes are listed in parentheses in the header (e.g., `class Sub(Super1, Super2)`).
- Assignments in the statement's suite generate *class attributes* inherited by instances: nested `def` statements make *methods*, while assignment statements make simple class members.
- Calling the class generates *instance objects*. Each instance object may have its own attributes, and inherits the attributes of the class and all of its superclasses.
- *Method functions* receive a special first argument, called `self` by very strong convention, which is the instance object that is the implied subject of the method call, and gives access to instance state information attributes.
- The `staticmethod()` and `classmethod()` built-ins support additional kinds of methods, and Python 3.X methods may be treated as simple functions when called through a class.
- Specially named *`__X__`* *operator overloading* methods intercept built-in operations.

- Where warranted, classes provide state retention and program structure, and support *code reuse* through customization in new classes.

### Class decorators in Python 3.X, 2.6, and 2.7

In Python 2.6, 3.0, and later in both lines, decorator syntax can be applied to class statements, in addition to function definitions. The class decorator syntax:

```
@decorator
class C:
   def meth():
       ...
```

is equivalent to this manual name rebinding:

```
class C:
     def meth():
       ...
C = decorator(C)
```

The effect is to rebind the class name to the result of passing the class through the *decorator* callable. Like function decorators, class decorators may be nested and support decorator arguments. Class decorators may be used to manage classes, or later instance-creation calls made to them (by using proxy objects).

### Metaclasses

Metaclasses are classes that generally subclass from the `type` class, in order to customize creation of class objects themselves. For example:

```
class Meta(type):
    def __new__(meta, cname, supers, cdict):
        # This and __init__ run by type.__call__
        c = type.__new__(meta, cname, supers, cdict)
        return c
```

In Python 3.X, classes define their metaclasses using keyword arguments in `class` headers:

```
class C(metaclass=Meta): ...
```

In Python 2.X, use class attributes instead:

```
class C(object):
    __metaclass__ = Meta
    ...
```

Metaclass code is run at the conclusion of a `class` statement (much like class decorators). See also `type()` in "Built-in Functions" for the mapping from `class` statements to metaclass methods.

## The try Statement

```
try:
    suite
except [type [as value]]:      # Or [, value] in 2.X
    suite
[except [type [as value]]:
    suite]*
[else:
    suite]
[finally:
    suite]

try:
    suite
finally:
    suite
```

The `try` statement catches exceptions. `try` statements can specify `except` clauses with suites that serve as handlers for exceptions raised during the `try` suite; `else` clauses that run if no exception occurs during the `try` suite; and `finally` clauses that run whether an exception happens or not. `except` clauses catch and recover from exceptions, and `finally` clauses run termination (block exit) actions.

Exceptions can be raised automatically by Python, or explicitly by code in `raise` statements (see "The raise Statement"). In `except` clauses, *type* is an expression giving the exception class to be

caught, and an extra variable name *value* can be used to intercept the instance of the exception class that was raised. Table 16 lists all the clauses that can appear in a `try` statement.

The `try` must have either an `except` or a `finally`, or both. The order of its parts must be: `try`→`except`→`else`→`finally`, where the `else` and `finally` are optional, and there may be zero or more `except` clauses, but there must be at least one `except` if an `else` appears. `finally` interacts correctly with `return`, `break`, and `continue`: if any of these pass control out of the `try` block, the `finally` clause is executed on the way out.

*Table 16. try statement clause formats*

| Clause format | Interpretation |
|---|---|
| `except:` | Catch all (or all other) exceptions |
| `except` *`type`*`:` | Catch a specific exception only |
| `except` *`type`* `as` *`value`*`:` | Catch exception and its instance |
| `except (`*`type1`*`,` *`type2`*`):` | Catch any of the exceptions |
| `except (`*`type1`*`,` *`type2`*`) as` *`value`*`:` | Catch any of the exceptions and its instance |
| `else:` | Run if no exceptions are raised |
| `finally:` | Always run this block on the way out |

Common variations include the following:

`except` *`classname`* `as` *`X`*`:`
: Catch a class exception, and assign *`X`* to the raised instance. *`X`* gives access to any attached state information attributes, print strings, or callable methods on the instance raised. For older string exceptions, *`X`* is assigned to the extra data passed along with the string (string exceptions are removed in both Python 3.X and 2.X, as of 3.0 and 2.6).

`except (`*`type1`*`,` *`type2`*`,` *`type3`*`) as` *`X`*`:`
: Catch any of the exceptions named in a tuple, and assign *`X`* to the extra data.

In Python 3.X, the name *X* in the `as` clause is *localized* to the `except` block, and removed when it exits; in 2.X, this name is not local to this block. See also the `sys.exc_info()` call in "The sys Module" for generic access to the exception class and instance (a.k.a., *type* and *value*) after an exception is raised.

### Python 2.X try statement forms

In Python 2.X, `try` statements work as described, but the `as` clause used in `except` handlers to access the raised instance is coded with a comma instead—both `as` and comma work in 2.6 and 2.7 (for 3.X compatibility), but `as` is not present in earlier 2.X:

`except` *`classname, X`*:
: Catch a class exception, and assign *X* to the raised instance (use `as` after 2.5).

`except (`*`name1, name2, name2`*`), `*`X`*:
: Catch any of the exceptions, and assign *X* to the extra data (use `as` after 2.5).

## The raise Statement

In Python 3.X, the `raise` statement takes the following forms:

```
raise instance [from (otherexc | None)]
raise class    [from (otherexc | None)]
raise
```

The first form raises a manually created instance of a class (e.g., `raise Error(args)`). The second form creates and raises a new instance of *`class`* (equivalent to `raise class()`). The third form reraises the most recent exception. See the next section ("Python 3.X chained exceptions") for the optional `from` clause.

The `raise` statement triggers exceptions. It may be used to explicitly raise either built-in exceptions or user-defined exceptions. See also "Built-in Exceptions" for exceptions predefined by Python.

On `raise`, control jumps to the matching `except` clause of the most recently entered `try` statement whose clause matches, or, if

none match, to the top level of the process where it ends the program and prints a standard error message. Any `finally` clauses are run along the way. An `except` clause is considered matching if it names the raised instance's class, or one of its superclasses (see "Class exceptions"). The instance object raised is assigned to the `as` variable in the matching `except` clause (if given).

### Python 3.X chained exceptions

In Python 3.X (only), the optional `from` clause allows exception chaining: *`otherexc`* is another exception class or instance, and is attached to the raised exception's `__cause__` attribute. If the raised exception is not caught, Python prints both exceptions as part of the standard error message:

```
try:
    ...
except Exception as E:
    raise TypeError('Bad') from E
```

As of Python 3.3, the `raise from` form can also specify `None`, to cancel any chained exceptions accumulated to the point of the statement's execution:

```
    raise TypeError('Bad') from None
```

### Class exceptions

As of Python 3.0 and 2.6, all exceptions are identified by classes, which must be derived from the built-in `Exception` class (in 2.X, this derivation is required of new-style classes only). The `Exception` superclass provides defaults for display strings, as well as constructor argument retention in tuple attribute `args`.

Class exceptions support exception *categories*, which can be easily extended. Because `try` statements catch all subclasses when they name a superclass, exception categories can be modified by altering the set of subclasses without breaking existing `try` statements. The raised instance object also provides storage for extra information about the exception:

```
class General(Exception):
    def __init__(self, x):
        self.data = x

class Specific1(General): pass
class Specific2(General): pass

try:
    raise Specific1('spam')
except General as X:
    print(X.data)            # Prints 'spam'
```

### Python 2.X raise statement forms

Prior to Python 2.6, Python 2.X allows exceptions to be identified with both strings and classes. Because of this, its `raise` statements may take the following forms, many of which exist for backward compatibility:

```
raise string              # Match same string object
raise string, data        # Assign data to exc var

raise class, instance     # Match class or any super
raise instance            # = inst.__class__, inst

raise class                 # = class()
raise class, arg            # = class(arg), noninst
raise class, (arg [, arg]*) # = class(arg, arg,...)
raise                       # Re-raise current exc
```

String exceptions were deprecated as of (and issue warnings in) Python 2.5. Python 2.X also allows a third item in `raise` statements, which must be a traceback object used instead of the current location as the place where the exception occurred.

## The assert Statement

```
assert expression [, message]
```

The `assert` statement performs debugging checks. If *`expression`* is false, it raises `AssertionError`, passing it *`message`* as its

constructor argument, if provided. The `-O` command-line flag removes assertions (their tests are neither included nor run).

## The with Statement

```
with expression [as variable]:          # 3.0/2.6, +
    suite

with expression [as variable]
        [, expression [as variable]]*:  # 3.1/2.7, +
    suite
```

The `with` statement wraps a nested block of code in a context manager (described ahead), which can run block entry actions, and ensure that block exit actions are run whether exceptions are raised or not. `with` can be an alternative to `try/finally` for exit actions, but only for objects having context managers.

*`expression`* is assumed to return an object that supports the context management protocol. This object may also return a value that will be assigned to the name *`variable`* if the optional `as` clause is present. Classes may define custom context managers, and some built-in types such as files and threads provide context managers with exit actions that close files, release thread locks, etc.:

```
with open(r'C:\misc\script', 'w') as myfile:
    ...process myfile, auto-closed on suite exit...
```

See "Files" for more details on file context manager usage, and Python manuals for other built-in types that support this protocol and statement.

This statement is supported as of Python 2.6 and 3.0, and may be enabled in 2.5 with the following:

```
from __future__ import with_statement
```

### Multiple context managers in Python 3.1 and 2.7

As of Python 3.1 and 2.7, the `with` statement may also specify multiple (a.k.a. *nested*) context managers. Any number of context manager items may be separated by commas, and multiple items work the same as nested `with` statements. In general, this code in 3.1, 2.7, and later:

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

is equivalent to the following, which also works in 3.0 and 2.6:

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

For example, in the following code, both files' exit actions are automatically run when the statement block exits, regardless of exception outcomes:

```
with open('data') as fin, open('res', 'w') as fout:
    for line in fin:
        fout.write(transform(line))
```

### Context manager protocol

Objects integrate with the `with` statement according to the following method-call model; see also "Methods for Context Managers":

1. The *`expression`* is evaluated, resulting in an object known as a context manager that must define method names `__enter__` and `__exit__`.
2. The context manager's `__enter__()` method is called. The value it returns is assigned to *`variable`* if present, or simply discarded otherwise.
3. The code in the nested *`suite`* is executed.

4. If the *suite* raises an exception, the `__exit__(`*type*, *value*, *traceback*`)` method is called with the exception details. If this method returns a false value, the exception is reraised; otherwise, the exception is terminated.
5. If the *suite* does not raise an exception, the `__exit__` method is still called, but its three arguments are all passed in as `None`.

## Python 2.X Statements

Python 2.X supports the `print` statement described earlier, does not support `nonlocal`, and does not support `with` fully until 2.6. In addition, `raise`, `try`, and `def` have the slightly different syntaxes in Python 2.X as noted earlier, and semantics noted as 3.X-specific in the preceding section do not generally apply to 2.X (e.g., namespace packages).

The following additional statement is available in Python 2.X only:

```
exec codestring [in globaldict [, localdict]]
```

The `exec` statement runs code dynamically. *`codestring`* may be any Python statement (or multiple statements separated by newlines) as a string, which is compiled and run in the namespace containing the `exec`, or the global/local namespace dictionaries if specified (*`localdict`* defaults to *`globaldict`*). *`codestring`* can also be a compiled code object. Also see `compile()`, `eval()`, and the Python 2.X `execfile()` in "Built-in Functions".

In Python 3.X, this statement becomes the `exec()` function (see "Built-in Functions"). The backward- and forward-compatible syntax `exec(a, b, c)` is also accepted in Python 2.X. Hint: do not use this to evaluate untrustworthy code strings, as they run as program code.

# Namespace and Scope Rules

This section discusses rules for name binding and lookup (see also the sections "Name format", "Name conventions", and "Atomic terms and dynamic typing"). In all cases, names are created when first assigned but must already exist when referenced. Qualified and unqualified names are resolved differently.

## Qualified Names: Object Namespaces

Qualified names—*X*, in *`object.X`*—are known as *attributes* and live in object namespaces. Assignments in some lexical scopes[4] serve to initialize object namespaces (e.g., module and class attributes):

*Assignment*: *`object.X = value`*

Creates or alters the attribute name *`X`* in the namespace of the *`object`*. This is the normal case; see "Formal Inheritance Rules" ahead for full details.

*Reference*: *`object.X`*

Searches for the attribute name *`X`* in the *`object`*, and then all accessible classes above it for instances and classes. This is the definition of *inheritance*; see "Formal Inheritance Rules" for full details.

## Unqualified Names: Lexical Scopes

Unqualified names—*X*, at the start of an expression—involve lexical scope rules. Assignments bind such names to the local scope unless they are declared global, or nonlocal in 3.X.

*Assignment*: *`X = value`*

Makes name *`X`* local by default: creates or changes name *`X`* in the current local scope. If *`X`* is declared `global`, this creates or changes name *`X`* in the enclosing module's scope. In

4. Lexical scopes refer to physically (syntactically) nested code structures in a program's source code.

Python 3.X only, if *X* is declared `nonlocal`, this changes name *X* in an enclosing function's scope. Local variables are normally stored in the call stack at runtime for quick access, and directly visible only to code in the same scope.

*Reference: X*
Looks for name *X* in at most four scope categories, in the following order:

a. The current *local* scope (the innermost enclosing function)

b. The local scopes of all lexically *enclosing functions* (other function layers, from inner to outer)

c. The current *global* scope (the enclosing module)

d. The *built-in* scope (which corresponds to module `builtins` in Python 3.X, and module `__builtin__` in Python 2.X)

Local and global scope contexts are defined in Table 17. `global` declarations make the search begin in the global scope instead, and `nonlocal` declarations in 3.X restrict the search to enclosing functions.

*Special cases: comprehensions, exceptions*
Python 3.X localizes loop variables in all *comprehensions* (Python 2.X does the same for all but list comprehensions). Python 3.X localizes and removes the exception variable in the `except` clause of `try` statements (2.X does not localize this name). See also "List comprehension expressions" and "The try Statement".

*Table 17. Unqualified name scopes*

| Code context | Global scope | Local scope |
|---|---|---|
| Module | Same as local | The module itself |
| Function, method | Enclosing module | Function definition/call |
| Class | Enclosing module | `class` statement |

| Code context | Global scope | Local scope |
|---|---|---|
| Script, interactive mode | Same as local | `module __main__` |
| `exec()`, `eval()` | Caller's global (or passed in) | Caller's local (or passed in) |

## Nested Scopes and Closures

The *enclosing functions* search of the previous section's "Reference" rules (step *b*) is called a *statically nested scope*, and was made standard as of version 2.2. For example, the following function works because the reference to `x` within `f2` has access to the enclosing `f1` scope:

```
def f1():
    x = 42
    def f2():
        print(x)    # Retain x in f1's scope
    return f2       # To be called later: f1()()=>42
```

Nested functions that retain enclosing scope references (e.g., `f2` in the preceding code) are known as *closures*—a state retention tool that is sometimes an alternative or complement to classes, and made more useful in 3.X with `nonlocal` (see "The nonlocal Statement"). Scopes nest arbitrarily, but only enclosing functions (not classes) are searched:

```
def f1():
    x = 42
    def f2():
        def f3():
            print(x)   # Finds x in f1's scope
        f3()           # f1() prints 42
    f2()
```

### Enclosing scopes and defaults

In Python versions prior to 2.2, the preceding section's functions fail because name `x` is not local (in the nested function's scope), global (in the module enclosing `f1`), or built-in. To make such cases work prior to version 2.2 or when required otherwise,

*default arguments* retain values from the immediately enclosing scope, because values of defaults are evaluated before entering a `def`:

```
def f1():
    x = 42
    def f2(x=x):
        print(x)       # f1()() prints 42
    return f2
```

This technique still works in more recent Python versions, and also applies to `lambda` expressions, which imply a nested scope just like `def` and are more commonly nested in practice:

```
def func(x):
    action = (lambda n: x ** n)      # Use as of 2.2
    return action                    # func(2)(4)=16

def func(x):
    action = (lambda n, x=x: x ** n) # Defaults alt
    return action                    # func(2)(4)=16
```

Though now largely outdated in most roles, defaults are still sometimes needed to reference *loop variables* when creating functions inside loops; otherwise, such variables reflect only their *final* loop value:

```
for I in range(N):
    actions.append(lambda I=I: F(I))  # Current I
```

# Object-Oriented Programming

Classes are Python's main *object-oriented programming* (OOP) tool. They support multiple instances, attribute inheritance, and operator overloading. Python also supports *functional programming* techniques—with tools such as generators, lambdas, comprehensions, maps, closures, decorators, and first-class function objects—which may serve as complement or alternative to OOP in some contexts.

## Classes and Instances

### Class objects provide default behavior

- The `class` statement creates a *class* object and assigns it to a name.
- Assignments inside `class` statements create class *attributes*, which are inherited object state and behavior.
- Class *methods* are nested `def`s, with special first arguments to receive the implied subject instance.

### Instance objects are generated from classes

- Calling a class object like a function makes a new *instance* object.
- Each instance object inherits class attributes and gets its own attribute *namespace*.
- Assignments to attributes of the first argument (e.g., `self.X = V`) in methods create per-instance *attributes*.

### Inheritance rules

- Inheritance happens at attribute qualification time: on `object.attribute`, if `object` is a class or instance.
- Classes inherit attributes from all classes listed in their class statement header line (superclasses). Listing more than one means *multiple inheritance*.
- Instances inherit attributes from the class from which they are generated, plus all that class's superclasses.
- Inheritance searches the instance, then its class, then all accessible superclasses, and uses the first version of an attribute name found. Superclasses are normally searched depth-first and then left to right, but new-style classes

search across before proceeding up in diamond pattern trees (only).

See "Formal Inheritance Rules" for more details on inheritance.

## Pseudoprivate Attributes

By default, all attribute names in modules and classes are visible everywhere. Special conventions allow some limited data hiding but are mostly designed to prevent name collisions (see also "Name conventions").

### Module privates

Names in modules with a single underscore (e.g., *_X*), and those not listed on the module's `__all__` list, are not copied over when a client uses `from` *`module`* `import *`. This is not strict privacy, however, as such names can still be accessed with other import statement forms.

### Class privates

Names anywhere within `class` statements with two leading underscores only (e.g., *__X*) are mangled at compile time to include the enclosing class name as a prefix (e.g., *_Class__X*). The added class-name prefix localizes such names to the enclosing class and thus makes them distinct in both the *`self`* instance object and the class hierarchy.

This helps to avoid unintended clashes that may arise for same-named methods, and for attributes in the single instance object at the bottom of the inheritance chain (for a given *`attr`*, all assignments to *`self.attr`* anywhere in a framework change the single instance namespace). This is not strict privacy, however, as such attributes can still be accessed via the mangled name.

Privacy-like access control can also be implemented with proxy classes that validate attribute access in `__getattr__()` and `__setattr__()` methods (see "Operator Overloading Methods").

## New-Style Classes

In Python 3.X, there is a single class model: all classes are considered *new-style* whether they derive from `object` or not. In Python 2.X, there are two class models: *classic*—the default in all 2.X; and *new-style*—an option in 2.2 and later, coded by deriving from a built-in type or the built-in `object` class (e.g., `class A(object)`).

New-style classes (including all classes in Python 3.X) differ from classic classes in the following ways:

- Diamond patterns of multiple inheritances have a slightly different search order—roughly, they are searched across before up, and more breadth-first than depth-first, per the new-style `__mro__` (see "Formal Inheritance Rules").
- Classes are now types, and types are now classes. The `type(I)` built-in returns the class an instance is made from, instead of a generic instance type, and is normally the same as `I.__class__`. The `type` class may be subclassed to customize class creation, and all classes inherit from `object`, which provides a small set of method defaults.
- The `__getattr__()` and `__getattribute__()` methods are no longer run for attributes implicitly fetched by built-in operations. They are not called for `__X__` operator-overloading method names by built-ins; the search for such names begins at classes, not instances. To intercept and delegate access to such method names, they generally must be redefined in wrapper/proxy classes.
- New-style classes have a set of new class tools, including slots, properties, descriptors, and the `__getattribute__()` method. Most of these have tool-building purposes. See "Operator Overloading Methods" for `__slots__`, `__getattribute__()`, and descriptor `__get__()`, `__set__()`, and `__delete__()` methods; see "Built-in Functions" for `property()`.

## Formal Inheritance Rules

Inheritance occurs on attribute name reference—the *`object.name`* lookup at the heart of object-oriented code—whenever *`object`* is derived from a class. It differs in classic and new-style classes, although typical code often runs the same in both models.

### Classic classes: DFLR

In classic classes (the default in 2.X), for name references, inheritance searches:

1. The *instance*
2. Then its *class*
3. Then all its class's *superclasses*, depth-first and then left to right

The first occurrence found along the way is used. This order is known as *DFLR*.

This reference search may be kicked off from either an instance or a class; attribute *assignments* normally store in the target object itself without search; and there are special cases for `__getattr__()` (run if the lookup failed to find a name) and `__setattr__()` (run for all attribute assignments).

### New-style classes: MRO

Inheritance in new-style classes (the standard in 3.X and an option in 2.X) employ the *MRO*—a linearized path through a class tree, and a nested component of inheritance, made available in a class's `__mro__` attribute. The MRO is roughly computed as follows:

1. List all the classes that an instance inherits from using the classic class's DFLR lookup rule, and include a class multiple times if it's visited more than once.

2. Scan the resulting list for duplicate classes, removing all but the last (rightmost) occurrence of duplicates in the list.

The resulting MRO sequence for a given class includes the class, its superclasses, and all higher superclasses up to and including the implicit or explicit `object` root class at the top of the tree. It's ordered such that each class appears before its parents, and multiple parents retain the order in which they appear in the `__bases__` superclass tuple.

Because common parents in *diamonds* appear only at the position of their *last* visitation in the MRO, lower classes are searched first when the MRO list is used later by attribute inheritance (making it more breadth-first than depth-first in diamonds only), and each class is included and thus visited just *once*, no matter how many classes lead to it.

The MRO ordering is used both by inheritance (ahead) and by the `super()` call—a built-in function that always invokes a *next* class on the MRO (relative to the call point), which might not be a superclass at all, but can be used to dispatch method calls throughout a class tree visiting each class just once.

## Example: nondiamonds

```
class D:       attr = 3           #   D:3   E:2
class B(D):    pass               #   |     |
class E:       attr = 2           #   B     C:1
class C(E):    attr = 1           #    \   /
class A(B, C): pass               #      A
X = A()                           #      |
print(X.attr)                     #      X

# DFLR = [X, A, B, D, C, E]
# MRO  = [X, A, B, D, C, E, object]
# Prints "3" in both 3.X and 2.X (always)
```

### Example: diamonds

```
class D:       attr = 3            #   D:3   D:3
class B(D):    pass                #   |     |
class C(D):    attr = 1            #   B     C:1
class A(B, C): pass                #    \   /
X = A()                            #      A
print(X.attr)                      #      |
                                   #      X
# DFLR = [X, A, B, D, C, D]
# MRO  = [X, A, B, C, D, object] (keeps last D only)
# Prints "1" in 3.X, "3" in 2.X ("1" if D(object))
```

### New-style inheritance algorithm

Depending on class code, new-style inheritance may involve descriptors, metaclasses, and MROs as follows (name sources in this procedure are attempted in order, either as numbered or per their left-to-right order in "or" conjunctions).

**To look up an attribute name:**

1. From an *instance* `I`, search the instance, its class, and its superclasses, as follows:
   a. Search the `__dict__` of all classes on the `__mro__` found at `I`'s `__class__`.
   b. If a data descriptor was found in step *a*, call its `__get__()` and exit.
   c. Else, return a value in the `__dict__` of the instance `I`.
   d. Else, call a nondata descriptor or return a value found in step *a*.
2. From a *class* `C`, search the class, its superclasses, and its metaclasses tree, as follows:
   a. Search the `__dict__` of all metaclasses on the `__mro__` found at `C`'s `__class__`.

b. If a data descriptor was found in step *a*, call its `__get__()` and exit.

c. Else, call a descriptor or return a value in the `__dict__` of a class on *C*'s own `__mro__`.

d. Else, call a nondata descriptor or return a value found in step *a*.

3. In both rule 1 and 2, *built-in* operations (e.g., expressions) essentially use just step *a* sources for their implicit lookup of method names, and `super()` lookup is customized.

In addition, method `__getattr__()` may be run if defined when an attribute is not found; method `__getattribute__()` may be run for every attribute fetch; and the implied `object` superclass provides some defaults at the top of every class and metaclass tree (that is, at the end of every MRO).

As *special cases*, built-in operations skip name sources as described in rule *3*, and the `super()` built-in function precludes normal inheritance. For objects returned by `super()`, attributes are resolved by a special context-sensitive scan of a limited portion of a class's MRO only, choosing the first descriptor or value found along the way, instead of running full inheritance (which is used on the `super` object itself only if this scan fails); see `super()` in "Built-in Functions".

**To assign an attribute name:**

A subset of the lookup procedure is run for attribute assignments:

- When applied to an *instance*, such assignments essentially follow steps *a* through *c* of rule *1*, searching the instance's class tree, although step *b* calls `__set__()` instead of `__get__()`, and step *c* stops and stores in the instance instead of attempting a fetch.
- When applied to a *class*, such assignments run the same procedure on the class's metaclass tree: roughly the same as rule *2*, but step *c* stops and stores in the class.

The `__setattr__()` method still catches all attribute assignments as before, although it becomes less useful for this method to use the instance `__dict__` to assign names, as some new-style extensions such as slots, properties, and descriptors implement attributes at the class level—a sort of "virtual" instance data mechanism. Some instances might not have a `__dict__` at all when slots are used (an optimization).

### New-style precedence and context

New-style inheritance procedures effectively impose precedence rules on the foundational operation of name resolution, which may be thought of as follows (with corresponding steps of the inheritance algorithm in parentheses):

*For instances, try:*

1. Class-tree data descriptors (*1b*)
2. Instance-object values (*1c*)
3. Class-tree nondata descriptors (*1d*)
4. Class-tree values (*1d*)

*For classes, try:*

1. Metaclass-tree data descriptors (*2b*)
2. Class-tree descriptors (*2c*)
3. Class-tree values (*2c*)
4. Metaclass-tree nondata descriptors (*2d*)
5. Metaclass-tree values (*2d*)

Python runs at most one (for rule 1) or two (for rule 2) tree searches per name lookup, despite the presence of four or five name sources. See also the preceding section's description of the special case lookup procedure run for objects returned by the new-style `super()` built-in function.

See also "Methods for Descriptors" and "Metaclasses" for their subjects; "Operator Overloading Methods" for usage details of `__setattr__()`, `__getattr__()`, and `__getattribute__()`; and Python's *object.c* and *typeobject.c* source code files, which host the implementations of instances and classes, respectively (in Python's source code distribution).

# Operator Overloading Methods

Classes may intercept and implement built-in operations by providing specially named method functions, all of which start and end with two underscores. These names are not reserved and can be inherited from superclasses as usual. Python locates and automatically calls at most one per operation.

Python calls a class's overloading methods when instances appear in expressions and other contexts. For example, if a class defines a method named `__getitem__`, and *X* is an instance of this class, the expression *X*`[`*i*`]` is equivalent to the method call *X*`.__getitem__(`*i*`)` (although, at present, using the method call form directly generally offers no speed advantage, and may even incur a penalty).

Overloading method names are somewhat arbitrary: a class's `__add__` method need not perform an addition or concatenation (although it normally should serve a similar role). Moreover, classes generally can mix numeric and collection methods and mutable and immutable operations. Most operator overloading names have no defaults (except those in `object` for new-style classes), and running an operation raises an exception if its corresponding method is not defined (e.g., `+` without `__add__`).

The following subsections enumerate available operation methods. In this section, trailing parentheses are normally omitted from *__X__* method names for brevity, as their context is implied. This section focuses on Python 3.X but gives operator overloading details common to most Python versions. See "Python 2.X Operator Overloading Methods" at the end of this section for items unique to Python lines.

## Methods for All Types

`__new__(cls [, arg]*)`
: Called to create and return a new instance of class *cls*. Receives constructor arguments *arg* passed to the class *cls*. If this returns an instance of the *cls* class, the instance's `__init__` method is then invoked with the new *self* instance, plus the same constructor arguments; else `__init__` is not run. Typically coded to call a superclass's `__new__` via explicit superclass name or `super()` (see "Built-in Functions"), and manage and return the resulting instance. This is an automatically static method.

  Not used in normal classes; intended to allow subclasses of immutable types to customize instance creation, and to allow custom *metaclasses* to tailor class creation. See also `type()` in "Built-in Functions" for the latter use case that invokes this method with class-creation arguments.

`__init__(self [, arg]*)`
: Invoked on *class*`(`*args*`...)`. This is the *constructor* method that initializes the new instance, *self*. When run for calls to a class name, *self* is provided automatically; *arg* is the arguments passed to the class name, and may be any function-definition argument form (see "The Expression Statement" and "The def Statement", including Table 14).

  Although technically called after `__new__`, `__init__` is the preferred way to configure new objects in all application-level classes. Must return no value, and if needed must call a superclass's `__init__` manually passing along the instance to *self*, via explicit superclass name or `super()` (see "Built-in Functions"). Python calls just one `__init__` automatically.

`__del__(self)`
: Invoked on instance garbage collection. This is the *destructor* method that cleans up when an instance *self* is freed (reclaimed). Embedded objects are automatically freed when their container is (unless referenced from elsewhere). Exceptions during this method's run are ignored and simply

print messages to `sys.stderr`. Hint: the `try/finally` statement allows more predictable termination actions for a code block; the `with` statement provides similar utility for supported object types.

`__repr__(`*`self`*`)`
: Invoked on `repr(`*`self`*`)`, interactive echoes, and nested appearances (as well as `` `self` `` in Python 2.X only). Also invoked on `str(`*`self`*`)` and `print(`*`self`*`)` if there is no `__str__`. This method generally returns a low-level "as code" string representation of *`self`*.

`__str__(`*`self`*`)`
: Invoked on `str(`*`self`*`)` and `print(`*`self`*`)` (or uses `__repr__` as a backup if defined). This method generally returns a high-level "user friendly" string representation of *`self`*.

`__format__(`*`self, formatspec`*`)`
: Called by the `format()` built-in function—and by extension, the `str.format()` method of `str` strings—to produce a "formatted" string representation of the *`self`* object, per the *`formatspec`* string whose syntax for built-in types is as given for the same-named component in `str.format()`. See "Formatting method syntax", "String formatting method" and "Built-in Functions". New as of Python 2.6 and 3.0.

`__bytes__(`*`self`*`)`
: Called by `bytes()` to return a `bytes` string representation of *`self`*, in Python 3.X only.

`__hash__(`*`self`*`)`
: Invoked on `dictionary[`*`self`*`]` and `hash(`*`self`*`)`, and other hashed collection operations, including those of the `set` object type. This method returns a unique and unchanging integer hash key, and interacts subtly with `__eq__`, both of which have defaults that ensure that all objects compare unequal except with themselves; see Python's manuals for more details.

`__bool__(self)`
: Called for truth value testing and the built-in `bool()` function; returns `False` or `True`. When `__bool__` is not defined, `__len__()` is called if it is defined and designates a true value with a nonzero length. If a class defines neither `__len__` nor `__bool__`, all its instances are considered true. New in Python 3.X; in Python 2.X, this method is named `__nonzero__` instead of `__bool__`, but works the same way.

`__call__(self[, arg]*)`
: Invoked on *`self`*`(`*`args...`*`)`, when an instance is called like a function. *`arg`* may take any function-definition argument form. For example, the following two definitions:

```
def __call__(self, a, b, c, d=5):
def __call__(self, *pargs, **kargs):
```

both match the following two calls:

```
self(1, 2, 3, 4)
self(1, *(2,), c=3, **dict(d=4))
```

See "The def Statement", including Table 14, for more on *`arg`* options.

`__getattr__(self, name)`
: Invoked on *`self.name`*, when *`name`* is an undefined attribute access (this method is not called if *`name`* exists in or is inherited by *`self`*). *`name`* is a string. This method returns an object or raises `AttributeError`.

Available in both classic and new-style classes. In both Python 3.X and new-style classes in 2.X, this is not run for *`__X__`* attributes implicitly fetched by *built-in operations* (e.g., expressions); redefine such names in wrapper/proxy classes or superclasses. See also `__dir__` in this list.

`__setattr__(self, name, value)`
: Invoked on *`self.name=value`* (all attribute assignments). Hint: assign through `__dict__` key or a superclass (e.g., `object`) to avoid recursive loops; a *`self.attr=x`* statement

within a __setattr__ calls __setattr__ again, but a *self*.__dict__['*attr*']=*x* does not.

Recursion may also be avoided by calling a new-style class's object superclass version explicitly: object.__setattr__(*self*, *attr*, *value*). This may be preferred or required in class trees that implement "virtual" instance attributes at the class level such as *slots*, *properties*, or *descriptors* (e.g., slots may preclude an instance __dict__).

__delattr__(*self*, *name*)
: Invoked on del *self*.*name* (all attribute deletions). Hint: this must avoid recursive loops by routing attribute deletions through __dict__ or a superclass, much like __setattr__.

__getattribute__(*self*, *name*)
: Called unconditionally to implement attribute accesses for instances of the class. If the class also defines __getattr__, it will never be called (unless it is called explicitly). This method should return the (computed) attribute value or raise an AttributeError exception. To avoid infinite recursion in this method, its implementation should always call the superclass method with the same name to access any attributes it needs (e.g., object.__getattribute__(*self*, *name*).

  Available in Python 3.X, and in 2.X for *new-style* classes only. In both, this is not run for __*X*__ attributes implicitly fetched by *built-in operations* (e.g., expressions); redefine such names in wrapper/proxy classes. See also __dir__ in this list.

__lt__(*self*, *other*)
__le__(*self*, *other*)
__eq__(*self*, *other*)
__ne__(*self*, *other*)
__gt__(*self*, *other*)
__ge__(*self*, *other*)
: Respectively, used on *self* < *other*, *self* <= *other*, *self* == *other*, *self* != *other*, *self* > *other*, and *self* >= *other*. Added in version 2.1, these are known as *rich comparison* methods

and are called for all comparison expressions in Python 3.X. For example, *X* < *Y* calls *X*.__lt__(*Y*) if defined. In Python 2.X only, these methods are called in preference to __cmp__, and __ne__ is also run for 2.X's *self* <> *other*.

These methods can *return* any value, but if the comparison operator is used in a Boolean context, the return value is interpreted as a Boolean result for the operator. These methods can also return (not raise) the special object NotImplemented if their operation is not supported for the operands (which works as though the method were not defined at all, and which forces Python 2.X to revert to the general __cmp__ method if defined).

There are no implied relationships among comparison operators. For example, *X* == *Y* being true does not imply that *X* != *Y* is false: __ne__ should be defined along with __eq__ if the operators are expected to behave symmetrically. There are also no right-side (swapped-argument) versions of these methods to be used when the left argument does not support the operation but the right argument does. __lt__ and __gt__ are each other's reflection, __le__ and __ge__ are each other's reflection, and __eq__ and __ne__ are their own reflections. Use __lt__ for sorting in Python 3.X, and see __hash__ in Python manuals for the role of __eq__ in hashing.

__slots__
: This class attribute can be assigned a string, sequence, or other iterable of strings giving the names of attributes of instances of the class. If defined in a *new-style* class (including all classes in Python 3.X), __slots__ generates a class-level management descriptor (see "Methods for Descriptors"); reserves space for the declared attributes in instances; and prevents the automatic creation of __dict__ for each instance (unless string '__dict__' is included in __slots__, in which case instances also have a __dict__ and attributes not named in __slots__ may be added dynamically).

Because they may suppress a `__dict__` per instance, slots can optimize space usage. However, they are generally discouraged unless clearly warranted in pathological cases, due both to their potential to break some types of code, and their complex usage constraints (see Python manuals for details).

To support classes with `__slots__`, tools that generically list attributes or access them by string name must generally use storage-neutral tools such as the `getattr()`, `setattr()`, and `dir()`, which apply to both `__dict__` and `__slots__` attribute storage.

`__instancecheck__(`*`self, instance`*`)`
Return true for `isinstance()` if *`instance`* is considered a direct or indirect instance of class. New in Python 3.X and 2.6; see Python manuals for usage.

`__subclasscheck__(`*`self, subclass`*`)`
Return true for `issubclass()` if *`subclass`* should be considered a direct or indirect subclass of class. New in Python 3.X and 2.6; see Python manuals for usage.

`__dir__(`*`self`*`)`
Called on `dir(`*`self`*`)` (see "Built-in Functions"). Returns a sequence of attribute names. Allows some classes to make their attributes known to introspection using `dir()`, when those attributes are computed dynamically with tools like `__getattr__` but are known to the class itself. Dynamic use cases may not qualify directly, but some *general proxies* may be able to delegate this call to proxied objects to support attribute tools. New in Python 3.X; also backported for use in Python 2.6 and 2.7.

## Methods for Collections (Sequences, Mappings)

`__len__(`*`self`*`)`
Invoked on `len(`*`self`*`)` and possibly for truth-value tests. This method returns a collection's size. For Boolean tests, Python looks for `__bool__` first, then `__len__`, and then

considers the object true (`__bool__` is named `__nonzero__` in Python 2.X). Zero length means false.

`__contains__(self, item)`
: Invoked on *item* `in` *self* for custom membership tests (otherwise, membership uses `__iter__`, if defined, or else `__getitem__`). This method returns a true or false result.

`__iter__(self)`
: Invoked on `iter(self)`. Added in version 2.2, this method is part of the *iteration protocol*. It returns an object with a `__next__` method (possibly *self*). The result object's `__next__()` method is then called repeatedly in all iteration contexts (e.g., `for` loops), and should return the next result or raise `StopIteration` to terminate the results progression.

  If no `__iter__` is defined, iteration falls back on `__getitem__`. A class `__iter__` method may also be coded with an embedded `yield` to return a generator with an automatically created `__next__`. In Python 2.X, `__next__` is named `next`. See also "The for Statement", and "The iteration protocol".

`__next__(self)`
: Invoked by the `next(self)` built-in function, and by all iteration contexts to advance through results. This method is part of the *iteration protocol*; see `__iter__` in this list for more usage details. New in Python 3.X; in Python 2.X, this method is named `next`, but works the same way.

`__getitem__(self, key)`
: Invoked on *self*`[`*key*`]`, *self*`[`*i*`:`*j*`:`*k*`]`, *x* `in` *self*, and possibly all iteration contexts. This method implements all indexing-related operations, including those for sequences and mappings. Iteration contexts (e.g., `in` and `for`) repeatedly index from `0` until `IndexError`, unless the preferred `__iter__` is defined. `__getitem__` and `__len__` constitute *sequence protocol*.

In Python 3.X, this and the following two methods are also called for *slice* operations, in which case *key* is a slice object. Slice objects may be propagated to another slice expression, and have attributes `start`, `stop`, and `step`, any of which can be `None` (for absent). See also `slice()` in "Built-in Functions".

`__setitem__(self, key, value)`
: Invoked on *self*`[`*key*`]=`*value*, *self*`[`*i*`:`*j*`:`*k*`]=`*value*. This method is called for assignment to a collection key or index, or to a sequence's slice.

`__delitem__(self, key)`
: Invoked on `del` *self*`[`*key*`]`, `del` *self*`[`*i*`:`*j*`:`*k*`]`. This method called is for index/key and sequence slice deletion.

`__reversed__(self)`
: Called if defined by the `reversed()` built-in function to implement custom reverse iteration. Returns a new iterable object that iterates over all the objects in the container in reverse order. If no `__reversed__` is defined, `reversed()` expects and uses sequence protocol (methods `__len__` and `__getitem__`).

## Methods for Numbers (Binary Operators)

Numeric (and comparison) methods that do not support their operation for the supplied arguments should return (not raise) the special built-in `NotImplemented` object, which works as though the method were not defined at all. Operations not supported for any operand types should be left undefined.

See Table 1 for example roles of operators in built-in types, although operator meaning is defined by overloading classes. For example, `__add__` is invoked on `+` for both numeric addition and sequence concatenation, but may have arbitrary semantics in new classes.

### Basic binary methods

`__add__(self, other)`
: Invoked on `self + other`.

`__sub__(self, other)`
: Invoked on `self - other`.

`__mul__(self, other)`
: Invoked on `self * other`.

`__truediv__(self, other)`
: Invoked on `self / other` in Python 3.X. In Python 2.X, `/` instead invokes `__div__` unless true division is enabled (see "Operator Usage Notes").

`__floordiv__(self, other)`
: Invoked on `self // other`.

`__mod__(self, other)`
: Invoked on `self % other`.

`__divmod__(self, other)`
: Invoked on `divmod(self, other)`.

`__pow__(self, other [, modulo])`
: Invoked on `pow(self, other [, modulo])` and `self ** other`.

`__lshift__(self, other)`
: Invoked on `self << other`.

`__rshift__(self, other)`
: Invoked on `self >> other`.

`__and__(self, other)`
: Invoked on `self & other`.

`__xor__(self, other)`
: Invoked on `self ^ other`.

`__or__(self, other)`
: Invoked on `self | other`.

### Right-side binary methods

`__radd__(self, other)`
`__rsub__(self, other)`
`__rmul__(self, other)`
`__rtruediv__(self, other)`
`__rfloordiv__(self, other)`
`__rmod__(self, other)`
`__rdivmod__(self, other)`
`__rpow__(self, other)`
`__rlshift__(self, other)`
`__rrshift__(self, other)`
`__rand__(self, other)`
`__rxor__(self, other)`
`__ror__(self, other)`

These are right-side counterparts to the binary operators of the preceding section. Binary operator methods have a right-side variant that starts with an `r` prefix (e.g., `__add__` and `__radd__`). Right-side variants have the same argument lists, but *`self`* is on the right side of the operator. For instance, *`self`* + *`other`* calls *`self`*`.__add__(`*`other`*`)`, but *`other`* + *`self`* invokes *`self`*`.__radd__(`*`other`*`)`.

The `r` right-side method is called only when the instance is on the right and the left operand is not an instance of a class that implements the operation:

- *`instance`* + *`noninstance`* runs `__add__`
- *`instance`* + *`instance`* runs `__add__`
- *`noninstance`* + *`instance`* runs `__radd__`

If two different class instances that overload the operation appear, the class on the left is preferred. `__radd__` often converts or swaps order and re-adds to trigger `__add__`.

### Augmented binary methods

`__iadd__(self, other)`
`__isub__(self, other)`
`__imul__(self, other)`
`__itruediv__(self, other)`
`__ifloordiv__(self, other)`
`__imod__(self, other)`
`__ipow__(self, other[, modulo])`
`__ilshift__(self, other)`
`__irshift__(self, other)`
`__iand__(self, other)`
`__ixor__(self, other)`
`__ior__(self, other)`

These are augmented assignment (in-place) methods. Respectively, they are called for the following assignment statement formats: `+=`, `-=`, `*=`, `/=`, `//=`, `%=`, `**=`, `<<=`, `>>=`, `&=`, `^=`, and `|=`. These methods should attempt to do the operation in-place (modifying *`self`*) and return the result (which can be *`self`*). If a method is not defined, the augmented operation falls back on the normal methods. To evaluate *`X`* `+=` *`Y`*, where *`X`* is an instance of a class that has an `__iadd__`, *`X`*`.__iadd__(`*`Y`*`)` is called. Otherwise, `__add__` and `__radd__` are considered.

## Methods for Numbers (Other Operations)

`__neg__(self)`
Invoked on `-`*`self`*.

`__pos__(self)`
Invoked on `+`*`self`*.

`__abs__(self)`
Invoked on `abs(`*`self`*`)`.

`__invert__(self)`
Invoked on `~`*`self`*.

`__complex__(self)`
: Invoked on `complex(self)`.

`__int__(self)`
: Invoked on `int(self)`.

`__float__(self)`
: Invoked on `float(self)`.

`__round__(self[, n])`
: Invoked on `round(self[, n])`. New in Python 3.X.

`__index__(self)`
: Called to implement `operator.index()`. Also called in other contexts where Python requires an integer object. This includes instance appearances as indexes, as slice bounds, and as arguments to the built-in `bin()`, `hex()`, and `oct()` functions. Must return an integer.

  Similar in Python 3.X and 2.X, but not called for `hex()` and `oct()` in 2.X (these require `__hex__` and `__oct__` methods in 2.X). In Python 3.X, `__index__` subsumes and replaces the `__oct__` and `__hex__` methods of Python 2.X, and the returned integer is formatted automatically.

## Methods for Descriptors

The following methods apply only when an instance of a class defining them (a *descriptor* class) is assigned to a class attribute of another class (known as the *owner* class). These methods in the descriptor are then automatically invoked for access to the attribute in the owner class and its instances:

`__get__(self, instance, owner)`
: Called to get the attribute of the owner class or of an instance of that class. *`owner`* is always the owner class; *`instance`* is the instance the attribute was accessed through, or `None` when the attribute is accessed through the owner class directly; *`self`* is the instance of the descriptor class. Return the attribute value or raise `AttributeError`. Both *`self`* and *`instance`* may have state information.

`__set__(self, instance, value)`
: Called to set the attribute on an *instance* of the owner class to a new *value*.

`__delete__(self, instance)`
: Called to delete the attribute on an *instance* of the owner class.

Descriptors and their methods are available for *new-style* classes, including all classes in 3.X. They are fully operational in 2.X only if both the descriptor and owner classes are new-style. A descriptor with a `__set__` is known as *data descriptor*, and is given precedence over other names in inheritance (see "Formal Inheritance Rules").

---

**NOTE**

The class "descriptors" here are distinct from "file descriptors" (see "Files" and "File Descriptor Tools" for the latter).

---

## Methods for Context Managers

The following methods implement the context manager protocol, used by the `with` statement (see also "The with Statement" for the mechanism that uses these methods):

`__enter__(self)`
: Enter the runtime context related to this object. The `with` statement assigns this method's return value to the target specified in the `as` clause of the statement (if any).

`__exit__(self, type, value, traceback)`
: Exit the runtime context related to this object. The parameters after *self* describe the exception that caused the context to be exited. If the context exited without an exception, all three arguments are `None`. Otherwise, arguments are the same as `sys.exc_info()` results (see "The sys Module").

Return a true value to prevent a raised exception from being propagated by the caller.

## Python 2.X Operator Overloading Methods

The preceding section notes semantic differences between operator overloading methods that are available in *both* Python 3.X and 2.X. This section notes content differences in the two lines.

Some of the methods described in the previous section work in 2.X for *new-style classes* only, which are an optional extension in the 2.X line. This includes `__getattribute__`, `__slots__`, and descriptor methods. Other methods may behave differently in 2.X for new-style classes (e.g., `__getattr__` for built-ins), and some methods are available in later 2.X releases only (e.g., `__dir__`, `__instancecheck__`, `__subclasscheck__`). The following gives methods unique to each line.

### Methods in Python 3.X only

The following methods are supported in Python 3.X but not Python 2.X:

- `__round__`
- `__bytes__`
- `__bool__` (use method name `__nonzero__` in Python 2.X, or `__len__`)
- `__next__` (use method name `next` in Python 2.X)
- `__truediv__` (available in Python 2.X only if true division is enabled: see "Operator Usage Notes")
- `__index__` for `oct()`, `hex()` usage (use `__oct__`, `__hex__` in Python 2.X)

### Methods in Python 2.X only

The following methods are supported in Python 2.X but not Python 3.X:

`__cmp__(self, other)` (and `__rcmp__`)
: Invoked on `self > other`, `other == self`, `cmp(self, other)`, etc. This method is called for all comparisons for which no more specific method (such as `__lt__`) is defined or inherited. It returns `-1`, `0`, or `1` for `self` less than, equal to, or greater than `other`. If no rich comparison or `__cmp__` methods are defined, class instances compare by their identity (address in memory). The `__rcmp__` right-side method is no longer supported as of version 2.1.

  In Python 3.X, use the more specific comparison methods described earlier: `__lt__`, `__ge__`, `__eq__`, etc. Use `__lt__` for sorting in Python 3.X.

`__nonzero__(self)`
: Invoked on truth-value (otherwise, uses `__len__` if defined).

  In Python 3.X, this method is renamed `__bool__`.

`__getslice__(self, low, high)`
: Invoked on `self[low:high]` for sequence slicing. If no `__getslice__` is found, and for extended three-item slices, a *slice object* is created and passed to the `__getitem__` method instead.

  In Python 2.X, this and the next two methods are considered deprecated but are still supported—they are called for slice expressions if defined, in preference to their item-based counterparts. In Python 3.X, these three methods are removed entirely—slices always invoke `__getitem__`, `__setitem__`, or `__delitem__` instead, with a slice object as its argument. See `slice()` in "Built-in Functions".

`__setslice__(self, low, high, value)`
: Invoked on `self[low:high]=value` for sequence slice assignment. See also `__getitem__` deprecation note earlier.

`__delslice__(self, low, high)`
: Invoked on `del self[low:high]` for sequence slice deletion. See also `__getitem__` deprecation note earlier.

`__div__(self, other)` (plus `__rdiv__`, `__idiv__`)
: Invoked on `self / other`, unless true division is enabled (in which case `__truediv__` is run instead). In Python 3.X, these are always subsumed by `__truediv__`, `__rtruediv__`, and `__itruediv__` because `/` is always true division. See also "Operator Usage Notes". Hint: assign `__truediv__ = __div__` to support both models in one method.

`__long__(self)`
: Invoked on `long(self)`. In Python 3.X, the `int` type subsumes the `long` type completely, so this method is removed.

`__oct__(self)`
: Invoked on `oct(self)`. This method returns an octal string representation. In Python 3.X, return an integer for `__index__()` instead.

`__hex__(self)`
: Invoked on `hex(self)`. This method returns a hex string representation. In Python 3.X, return an integer for `__index__()` instead.

`__coerce__(self, other)`
: Invoked on the mixed-mode arithmetic expression, `coerce()`. This method returns a tuple of `(self, other)` converted to a common type. If `__coerce__` is defined, it is generally called before any real operator methods are tried (e.g., before `__add__`). It should return a tuple containing operands converted to a common type (or `None` if it can't convert). See the Python Language Reference for more on coercion rules.

`__unicode__(self)`
: Called by 2.X on `unicode(self)` to return a Unicode string for `self` (see "Python 2.X Built-in Functions"). This is the Unicode equivalent of `__str__`.

`__metaclass__`
: Class attribute assigned to the class's metaclass. In Python 3.X, use instead `metaclass=M` keyword argument syntax in the class header line (see "Metaclasses").

# Built-in Functions

All built-in names (functions, exceptions, and so on) exist in the implied outer built-in scope, which corresponds to the `builtins` module (named `__builtin__` in Python 2.X). Because this scope is always searched last on name lookups, these functions are always available in programs without imports. However, their names are not reserved words and might be hidden (shadowed) by assignments to the same name in global or local scopes. Run `help(`*`function`*`)` for extra details on any call here.

This section focuses on Python 3.X but gives built-in function details common to most Python versions. See "Python 2.X Built-in Functions" at the end of this section for items unique to Python lines:

`abs(`*`N`*`)`
: Returns the absolute value of a number *`N`*.

`all(`*`iterable`*`)`
: Returns `True` only if all elements of the *`iterable`* are true.

`any(`*`iterable`*`)`
: Returns `True` only if any element of the *`iterable`* is true. Hint: `filter(bool,` *`I`*`)` and `[x for x in` *`I`* `if x]` both collect all true values in an iterable *`I`*.

`ascii(`*`object`*`)`
: Like `repr()`, returns a string containing a printable representation of an object, but escapes the non-ASCII characters in the `repr()` result string using `\x`, `\u`, or `\U` escapes. This result is similar to that returned by `repr()` in Python 2.X.

`bin(N)`
: Converts an integer number to a binary (base 2) digits string. The result is a valid Python expression. If argument *N* is not a Python `int` object, it must define an `__index__()` method that returns an integer. Hint: see also `int(string, 2)` to convert from binary, `0bNNN` binary literals in code, and the `b` type code in `str.format()`.

`bool([X])`
: Returns the Boolean value of object *X*, 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`. The class `bool` cannot be subclassed further. Its only instances are `False` and `True`.

`bytearray([arg [, encoding [, errors]]])`
: Returns a new array of bytes. The `bytearray` type is a mutable sequence of small integers in the range `0...255`, which prints as ASCII text when possible. It is essentially a mutable variant of `bytes`, which supports most operations of mutable sequences, as well as most methods of the `str` string type. *arg* may be a `str` string with `encoding` name (and optionally `errors`) as in `str()` (described later in this list); an integer size to initialize an array of NULL (zero value) bytes; an iterable of small integers used to initialize the array such as a `bytes` string or another `bytearray`; an object conforming to the memory-view (previously known as buffer) interface used to initialize the array; or absent, to create a zero-length array. See also "byte and bytearray strings".

`bytes([arg [, encoding [, errors]]])`
: Returns a new `bytes` object, which is an immutable sequence of integers in the range `0...255`. `bytes` is an immutable version of `bytearray`. It has the same nonmutating string methods and sequence operations. It is commonly used to represent 8-bit byte strings of binary data (e.g., media, encoded Unicode text). Constructor arguments are interpreted as for `bytearray()`. `bytes` objects may also be created with the

`b'ccc'` literal in Python 3.X (in 2.X, this makes a normal `str`). See also "byte and bytearray strings".

`callable(`*`object`*`)`
: Returns `True` if *`object`* is callable; otherwise, returns `False`. This call is present in 2.X. In 3.X, it was removed in Python 3.0 and 3.1, but restored as of 3.2; in earlier 3.X, use `hasattr(`*`object`*`, '__call__')` instead.

`chr(`*`I`*`)`
: Returns a one-character string whose Unicode code point is integer *`I`*. This is the inverse of `ord()` (e.g., `chr(97)` is `'a'` and `ord('a')` is `97`).

`classmethod(`*`function`*`)`
: Returns a class method for a *`function`*. A class method receives the most specific (lowest) class of the subject instance as an implicit first argument, just like an instance method receives the instance. Useful for managing per-class data. Use the `@classmethod` function decorator form in version 2.4 and later (see "The def Statement").

`compile(`*`string`*`, `*`filename`*`, `*`kind`*`[, `*`flags`*`[, `*`dont_inherit`*`]])`
: Compiles *`string`* into a code object. *`string`* is a Python string containing Python program code. *`filename`* is a string used in error messages (and is usually the name of the file from which the code was read, or `'<string>'` if typed interactively). *`kind`* can be `'exec'` if *`string`* contains statements; `'eval'` if *`string`* is an expression; or `'single'`, which prints the output of an expression statement that evaluates to something other than `None`. The resulting code object can be executed with `exec()` or `eval()` built-in function calls. The optional last two arguments control which future statements affect the string's compilation; if absent, the string is compiled with the future statements in effect at the place of the `compile()` call (see Python manuals for more details).

`complex([real [, imag]])`
: Builds a complex number object (this can also be coded using the `J` or `j` suffix: *`real`*`+`*`imag`*`J`). *`imag`* defaults to `0`. If both arguments are omitted, returns `0j`.

`delattr(object, name)`
: Deletes the attribute named *`name`* (a string) from *`object`*. Similar to `del` *`object.name`*, but *`name`* is a string, not a variable taken literally (e.g., `delattr(a, 'b')` is like `del a.b`).

`dict([mapping | iterable | keywords])`
: Returns a new dictionary initialized from a mapping; a sequence or other iterable of key/value pairs; or a set of keyword arguments. If no argument is given, it returns an empty dictionary. This is a subclassable type class name.

`dir([object])`
: If no argument is passed, this returns the list of names in the current local scope (namespace). When any *`object`* with attributes is passed as an argument, it returns the list of attribute names associated with that *`object`*. Works on modules, classes, and class instances, as well as built-in objects with attributes (lists, dictionaries, etc.). Its result includes inherited attributes, and is sorted; use `__dict__` attributes for attribute lists of a single object only. This call runs a custom *`object`*`.__dir__()` if defined, which may provide names of computed attributes in dynamic or proxy classes.

`divmod(X, Y)`
: Returns a tuple of (*`X`* `/` *`Y`*, *`X`* `%` *`Y`*).

`enumerate(iterable, start=0)`
: Returns an iterable `enumerate` object. *`iterable`* must be a sequence or other iterable object that supports the iteration protocol. The `__next__()` method of the iterator returned by `enumerate()` returns a tuple containing a *count* (from `start`, or zero by default) and the corresponding *value* obtained from iterating over *`iterable`*. Useful for obtaining an indexed series of both positions and items, in iterations such as `for` loops (e.g., `(0, x[0])`, `(1, x[1])`, `(2, x[2])`, ...).

Available in version 2.3 and later. See also "The enum Module" for fixed enumerations in Python 3.4.

`eval(`*`expr`*`[, `*`globals`*`[, `*`locals`*`]])`
: Evaluates *`expr`*, which is assumed to be either a Python string containing a Python expression or a compiled code object. *`expr`* is evaluated in the namespace scopes of the *`eval`* call itself, unless the *`globals`* and/or *`locals`* namespace dictionary arguments are passed. *`locals`* defaults to *`globals`* if only *`globals`* is passed. This call returns the *`expr`* result. Also see the `compile()` function earlier in this section to precompile, and the `exec()` built-in, later in this section, to run statement strings. Hint: do not use this to evaluate untrustworthy code strings, as they run as program code.

`exec(`*`stmts`*`[, `*`globals`*`[, `*`locals`*`]])`
: Evaluates *`stmts`*, which is assumed to be either a Python string containing Python statements or a compiled code object. If *`stmts`* is a string, the string is parsed as a suite of Python statements, which is then executed unless a syntax error occurs. If it is a code object, it is simply executed. *`globals`* and *`locals`* work the same as in `eval()`, and `compile()` may be used to precompile to code objects. This is available as a statement form in Python 2.X (see "Python 2.X Statements"), and has morphed between statement and function forms more than once in Python's history. Hint: do not use this to evaluate untrustworthy code strings, as they run as program code.

`filter(`*`function, iterable`*`)`
: Returns those elements of *`iterable`* for which *`function`* returns a true value. *`function`* takes one parameter. If *`function`* is `None`, this returns all the true items in *`iterable`*—which is the same as passing the built-in `bool` to *`function`*.

  In Python 2.X, this call returns a *list*. In Python 3.X, it returns an *iterable* object that generates values on demand and can be traversed only once (wrap in a `list()` call to force results generation if required).

`float([X])`
: Converts a number or a string *X* to a floating-point number (or `0.0` if no argument is passed). See also "Numbers" for example uses. This is a subclassable type class name.

`format(value [, formatspec])`
: Converts an object *value* to a formatted representation, as controlled by string *formatspec*. The interpretation of *formatspec* depends on the type of the *value* argument; a standard formatting syntax is used by most built-in types, described for the string formatting method earlier in this book (see *formatspec* in "Formatting method syntax"). `format(value, formatspec)` calls `value.__format__(formatspec)`, and is a base operation of the `str.format()` method (e.g., `format(1.3333, '.2f')` is equivalent to `'{0:.2f}'.format(1.3333)`).

`frozenset([iterable])`
: Returns a *frozen set* object whose elements are taken from *iterable*. Frozen sets are immutable sets that have no update methods, and may be nested in other sets.

`getattr(object, name [, default])`
: Returns the value of attribute *name* (a string) from *object*. Similar to `object.name`, but *name* evaluates to a string, and is not a variable name taken literally (e.g., `getattr(a, 'b')` is like `a.b`). If the named attribute does not exist, *default* is returned if provided; otherwise, `AttributeError` is raised.

`globals()`
: Returns a dictionary containing the caller's global variables (e.g., the enclosing module's names).

`hasattr(object, name)`
: Returns `True` if *object* has an attribute called *name* (a string); `False` otherwise.

`hash(object)`
: Returns the hash value of *`object`* (if it has one). Hash values are integers used to quickly compare dictionary keys during a dictionary lookup. Invokes *`object`*`.__hash__()`.

`help([object])`
: Invokes the built-in help system. This function is intended for interactive use. If no argument is given, an interactive help session starts in the interpreter console. If the argument is a string, it is looked up as the name of a module, function, class, method, keyword, or documentation topic, and its help text is displayed. If the argument is any other kind of object, help for that object is generated (e.g., `help(list.pop)`)

`hex(N)`
: Converts an integer number *`N`* to a hexadecimal (base 16) digits string. If argument *`N`* is not a Python `int` object, in Python 3.X it must define an `__index__()` method that returns an integer (in 2.X, `__hex__()` is called instead).

`id(object)`
: Returns the identity integer of *`object`*, which is unique for the calling process among all existing objects (i.e., its address in memory).

`__import__(name, [...other args...])`
: Imports and returns a module, given its *`name`* as a string at runtime (e.g., `mod = __import__('mymod')`). This call is generally faster than constructing and executing an `import` statement string with `exec()`. This function is called by `import` and `from` statements internally and can be overridden to customize import operations. All arguments but the first have advanced roles; see the Python Library Reference. See also the standard library's `imp` module and `importlib.import_module()` call, as well as "The import Statement".

`input([prompt])`
: Prints a *`prompt`* string if given, and then reads a line from the *stdin* input stream (`sys.stdin`) and returns it as a string. It

strips the trailing \n at the end of the line and raises EOFError at the end of the *stdin* stream. On platforms where GNU readline is supported, input() uses it. In Python 2.X, this function is named raw_input().

int([*number* | *string* [, *base*]])
: Converts a number or string to a plain integer. Conversion of floating-point numbers to integers truncates toward 0. *base* can be passed only if the first argument is a string, and defaults to 10. If *base* is passed as 0, the base is determined by the string's contents (as a code literal); otherwise, the value passed for *base* is used for the base of the conversion of the string. *base* may be 0, and 2...36. The string may be preceded by a sign and surrounded by ignored whitespace. If no arguments, returns 0. See also "Numbers" for example uses. This is a subclassable type class name.

isinstance(*object*, *classinfo*)
: Returns True if *object* is an instance of *classinfo*, or an instance of any subclass thereof. *classinfo* can also be a tuple of classes and/or types. In Python 3.X, types are classes, so there is no special case for types. In Python 2.X, the second argument can also be a type object, making this function useful in both Pythons as an alternative type-testing tool (isinstance(*X*, *Type*) versus type(*X*) is *Type*).

issubclass(*class1*, *class2*)
: Returns True if *class1* is derived from *class2*. *class2* can also be a tuple of classes.

iter(*object* [, *sentinel*])
: Returns an iterator object that can be used to step through items in iterable *object*. Iterator objects returned have a __next__() method that returns the next item or raises StopIteration to end the progression. All iteration contexts in Python use this protocol to advance, if supported by *object*. The next(*I*) built-in function also calls *I*.__next__() automatically. If one argument, *object* is assumed to provide its own iterator or be a sequence; if two arguments, *object* is a callable that is called until it returns

*sentinel*. The `iter()` call can be overloaded in classes with `__iter__()`.

In Python 2.X, iterator objects have a method named `next()` instead of `__next__()`. For forward and backward compatibility, the `next()` built-in function is also available in 2.X (as of 2.6) and calls *I*`.next()` instead of *I*`.__next__()`. Prior to 2.6, *I*`.next()` may be called explicitly instead. See also `next()` in this list, and "The iteration protocol".

`len(`*object*`)`
: Returns the number of items (length) in a collection *object*, which may be a sequence, mapping, set, or other (e.g., a user-defined collection).

`list([`*iterable*`])`
: Returns a new list containing all the items in any *iterable* object. If *iterable* is already a list, it returns a (shallow) copy of it. If no arguments, returns a new empty list. This is a subclassable type class name.

`locals()`
: Returns a dictionary containing the local variables of the caller (with one *key*`:`*value* entry per local).

`map(`*function*`,` *iterable* `[,` *iterable*`]*)`
: Applies *function* to each item of any sequence or other iterable object *iterable*, and returns the individual results. For example, `map(abs, (1, -2))` returns `1` and `2`. If additional iterable arguments are passed, *function* must take that many arguments, and is passed one item from each *iterable* on every call; in this mode, iteration stops at the end of the shortest iterable.

  In Python 2.X, this returns a *list* of the individual call results. In Python 3.X, it instead returns an *iterable* object that generates results on demand and can be traversed only once (wrap it in a `list()` call to force results generation if required).

Also in Python 2.X (but not Python 3.X), if *function* is None, map() collects all the *iterable* items into a result list; for multiple iterables, the result combines their items in tuples, and all iterables are padded with Nones to the length of the longest. Similar utility is available in Python 3.X in standard library module itertools.

max(*iterable* [, *arg*]* [, key=*func*])
: With a single argument *iterable*, returns the highest-valued item of a nonempty iterable (e.g., string, tuple, list, set). With more than one argument, it returns the highest value among all the arguments. The optional keyword-only key argument specifies a one-argument value transform function like that used for list.sort() and sorted() (see "Lists" and "Built-in Functions").

memoryview(*object*)
: Returns a memory view object created from the given *object* argument. Memory views allow Python code to access the internal data of an object that supports the protocol without copying the object. Memory can be interpreted as simple bytes or more complex data structures. Built-in objects that support the memory-view protocol include bytes and bytearray. See Python manuals; memory views are largely a replacement for the Python 2.X buffer() protocol and built-in function, although memoryview() is backported to Python 2.7 for 3.X compatibility.

min(*iterable* [, *arg*]* [, key=*func*])
: With a single argument *iterable*, returns the lowest-valued item of a nonempty iterable (e.g., string, tuple, list, set). With more than one argument, it returns the lowest value among all the arguments. The key argument is as in max() (in this list).

next(*iterator* [, *default*])
: Retrieves the next item from the *iterator* object by calling its __next__() method (in 3.X). If the *iterator* is exhausted, *default* is returned if given; otherwise, StopIteration is raised. This function is also available in Python 2.6 and 2.7,

where it calls *iterator*.next() instead of *iterator*.__next__(). This aids 2.X forward compatibility with 3.X, and 3.X backward compatibility with 2.X. In Python 2.X prior to 2.6, this call is missing; use *iterator*.next() manually instead for manual iterations. See also iter() in this list, and "The iteration protocol".

object()
: Returns a new featureless object. object (its literal name) is a superclass to all new-style classes, which includes all classes in Python 3.X, and classes explicitly derived from object in Python 2.X. It has a small set of default methods (see dir(object)).

oct(*N*)
: Converts a number *N* to an octal (base 8) digits string. If argument *N* is not a Python int object, in Python 3.X it must define an __index__() method that returns an integer (in 2.X, __oct__() is called instead).

```
open(...)
        open(file
           [, mode='r'
           [, buffering=-1
           [, encoding=None          # Text mode only
           [, errors=None            # Text mode only
           [, newline=None           # Text mode only
           [, closefd=True,          # Descriptors only
           [, opener=None  ]]]]]]]) # Custom opener 3.3+
```

Returns a new *file object* connected to the external file named by *file*, or raises IOError (or an OSError subclass as of 3.3) if the open fails. This section describes Python 3.X's open(); for Python 2.X usage, see "Python 2.X Built-in Functions".

*file* is usually a text or bytes string object giving the name (including its path if the file isn't in the current working directory) of the file to be opened. *file* may also be 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`. All the following options may be passed as keyword arguments.

`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. In text mode, if `encoding` is not specified, the encoding used is platform dependent, and newlines are translated to and from `'\n'` by default. For reading and writing raw bytes, use binary modes `'rb'`, `'wb'`, or `'ab'`, and leave `encoding` unspecified.

Available modes that may be combined: `'r'` for read (default); `'w'` for write, truncating the file first; `'a'` for write, appending to the end of the file if it exists; `'b'` for binary mode; `'t'` for text mode (default); `'+'` to open a disk file for updating (reading and writing); `'U'` for universal newline mode (for backward compatibility only). The default `'r'` mode is the same as `'rt'` (open for reading text). For binary random access, the mode `'w+b'` opens and truncates the file to zero 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 does not:

- For *input*, files opened in binary mode (by appending `'b'` to `mode`) return contents as `bytes` objects without any Unicode decoding or line-end translations. In text mode (the default, or when `'t'` is appended to `mode`), the contents of the file are returned as `str` strings after the bytes are decoded using either an explicitly passed Unicode `encoding` name or a platform-dependent default, and line-ends are translated per `newline`.
- For *output*, binary mode expects a `bytes` or `bytearray` and writes it unchanged. Text mode expects a `str`, and encodes it per a Unicode `encoding` and applies line-end translations per `newline` before writing.

`buffering` is an optional integer used to set buffering policy. By default (when not passed or value `-1`), full buffering is on. Pass `0` to switch buffering off (allowed in binary mode only); `1` to set line buffering (only in text mode); and an integer `> 1` for full buffering and buffer size. Buffered data transfers might not be immediately fulfilled (use `file.flush()` to force buffers to be emptied).

`encoding` is the name of the encoding used to decode or encode a text file's content on transfers. This should be used in text mode only. The default encoding is platform dependent (obtained from `locale.getpreferredencoding()`), but any encoding supported by Python can be passed. See the `codecs` module in the Python standard library for the list of supported encodings.

`errors` is an optional string that specifies how to handle encoding errors. This should be used in text mode only. It may be passed `'strict'` (the default, for `None`) to raise a `ValueError` exception on encoding errors; `'ignore'` to ignore errors (but ignoring encoding errors can result in data loss); `'replace'` to use a replacement marker for invalid data; and more. See Python manuals and `codecs.register_error()` in Python's standard library for permitted error values, and `str()` in this list for related tools.

`newline` controls how universal newlines work, and applies to text mode only. It can be `None` (the default), `''`, `'\n'`, `'\r'`, and `'\r\n'`:

- On *input*, if `newline` is `None`, universal newlines mode is enabled: lines may end in `'\n'`, `'\r'`, or `'\r\n'`, and all these are translated to `'\n'` before being returned to the caller. If `newline` is `''`, universal newline mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are terminated only 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 it is any of the other legal values, any `'\n'` characters written are translated to the given string.

If `closefd` is `False`, the underlying file descriptor will be kept open when the file is closed. This does not work when a file name is given as a string and must be `True` (the default) in that case. If `opener` is passed a callable in Python 3.3 and later, a file descriptor is obtained by *`opener`*`(file, `*`flags`*`)`, with arguments as for `os.open()` (see "The os System Module").

See also "Files" for the interface of objects returned by `open()`. Hint: any object that supports the file object's method interface can generally be used in contexts that expect a file (e.g., see *`socketobj`*`.makefile()`, Python 3.X's `io.StringIO(`*`str`*`)` and `io.BytesIO(`*`bytes`*`)`, and Python 2.X's `StringIO.stringIO(`*`str`*`)`, all in the Python standard library).

---

**NOTE**

Because file mode implies both configuration options and string datatypes in 3.X, it is useful to think of `open()` in terms of *two distinct flavors*—text and binary, as specified in the mode string. Python developers chose to overload a single function to support the two file types, with mode-specific arguments and differing content types, rather than provide two separate `open()` functions. The underlying `io` class library—to which `open()` is a frontend in 3.X—*does* specialize file object types for modes. See Python manuals for more on the `io` module. `io` is also available in 2.X as of 2.6 as an alternative to its built-in `file` type, but is the normal file interface for `open()` in 3.X.

---

`ord(C)`
: Returns an integer code point value of a one-character string *C*. For ASCII characters, this is the 7-bit ASCII code of *C*; in general, this is the Unicode code point of a one-character Unicode string *C*. See also this call's `chr()` inverse in this list.

`pow(X, Y [, Z])`
: Returns *X* to power *Y* [modulo *Z*]. This is similar to the `**` expression operator.

```
print(...)
        print([object [, object]*]
             [, sep=' '] [, end='\n']
             [, file=sys.stdout] [, flush=False])
```

: Prints optional *object*(s) to the stream `file`, separated by `sep`, followed by `end`, with an optional post-printing forced `flush`. The last four arguments, if present, must be given as keyword arguments, and default as shown; `flush` is available as of Python 3.3.

: All nonkeyword arguments are converted to strings using the equivalent of `str()`, and written to the stream. Both `sep` and `end` must either be strings, or `None` (meaning use their default values). If no *object* is given, `end` is written. `file` must be an object with a `write(`*string*`)` method, but need not be an actual file; if it is not passed or is `None`, `sys.stdout` will be used.

: Print functionality is available as a statement form in Python 2.X. See also "The print Statement".

`property([fget[, fset[, fdel[, doc]]]])`
: Returns a property attribute for new-style classes (classes that derive from `object`, including all in 3.X). *fget* is a function for getting an attribute value, *fset* is a function for setting, and *fdel* is a function for deleting. This call may be used as a function decorator itself (`@property`), and returns an object with methods *getter*, *setter*, and *deleter*, which may also be used as decorators in this role (see "The def

Statement"). Implemented with descriptors (see "Methods for Descriptors").

`range([start,] stop [, step])`
: Returns successive integers between *start* and *stop*. With one argument, it returns integers from `0` through *stop*`-1`. With two arguments, it returns integers from *start* through *stop*`-1`. With three arguments, it returns integers from *start* through *stop*`-1`, adding *step* to each predecessor in the result. *start*, *step* default to `0`, `1`.

  *step* may be `> 1` to skip items (`range(0, 20, 2)` is a list of even integers from `0` through `18`), or negative to count down from the *start* high value (`range(5, -5, -1)` is `5` through `-4`). This call is often used to generate offset lists or repeat counts in `for` loops and other iterations.

  In Python 2.X, this call returns a *list*. In Python 3.X, it returns an *iterable* object that generates values on demand and can be traversed multiple times (wrap in a `list()` call to force results generation if required).

`repr(object)`
: Returns the lower-level "as-code" printable string representation of `object`. The string generally takes a form potentially parseable by `eval()`, or gives more details than `str()` (in this list). In Python 2.X only, this is equivalent to `` `object` `` (the backquotes expression, removed in Python 3.X). See `__repr__()` in "Operator Overloading Methods".

`reversed(seq)`
: Returns a reverse iterable. *seq* must be an object that has a `__reversed__()` method or supports the sequence protocol (the `__len__()` method, and the `__getitem__()` method called with integer arguments starting at `0`).

`round(X [, N])`
: Returns the floating-point value *X* rounded to *N* digits after the decimal point. *N* defaults to zero, and may be negative to denote digits to the left of the decimal point. The return value is an integer if called with one argument; otherwise, it

is of the same type as *X*. In Python 2.X only, the result is always a floating-point. In Python 3.X only, this calls *X*.__round__().

set([*iterable*])
: Returns a set whose elements are taken from *iterable*. The elements must be immutable. To represent sets of sets, the nested sets should be frozenset objects. If *iterable* is not specified, this returns a new empty set. Available since version 2.4. See also "Sets", and the {...} set literal in Python 3.X and 2.7.

setattr(*object*, *name*, *value*)
: Assigns *value* to the attribute *name* (a string) in *object*. Similar to *object.name* = *value*, but *name* evaluates to a string, and is not a variable name taken literally (e.g., setattr(a, 'b', c) is equivalent to a.b = c).

slice([*start* ,] *stop* [, *step*])
: Returns a slice object representing a range, with read-only attributes *start*, *stop*, and *step*, any of which can be None. Arguments are interpreted the same as for range(). Slice objects may be used in place of *i*:*j*:*k* slice notation (e.g., *X*[*i*:*j*] is equivalent to *X*[slice(*i*, *j*)]).

sorted(*iterable*, key=None, reverse=False)
: Returns a new sorted list from the items in *iterable*. The optional keyword arguments key and reverse have the same meaning as those for the list.sort() method described in "Lists"; key is a one-argument value transform function. This works on any iterable and returns a new object instead of changing a list in-place, and is thus useful in for loops (and more) to avoid splitting sort calls out to separate statements due to None returns. Available in version 2.4 and later.

  In Python 2.X, this has call signature sorted(*iterable*, cmp=None, key=None, reverse=False), where optional arguments cmp, key, and reverse have the same meaning as those for the Python 2.X list.sort() method described earlier in "Lists".

`staticmethod(`*`function`*`)`
: Returns a static method for *`function`*. A static method does not receive an instance as an implicit first argument, and so is useful for processing class attributes that span instances. Use the `@staticmethod` function decorator in version 2.4 and later (see "The def Statement"). In Python 3.X only, this built-in is not required for simple functions in classes called only through class objects (and never through instance objects).

`str([`*`object`*`[, `*`encoding`*`[, `*`errors`*`]]])`
: This call (which is also a subclassable type name) operates in one of two modes in Python 3.X determined by call pattern:

  - *Print string*: when only *`object`* is given, this returns the higher-level "user-friendly" printable string representation of *`object`*. For strings, this is the string itself. Unlike `repr(`*`X`*`)`, `str(`*`X`*`)` does not always attempt to return a string that is acceptable to `eval()`; its goal is to return a readable and printable string. With no arguments, this returns the empty string. See also `__str__()` in "Operator Overloading Methods", invoked by this mode.
  - *Unicode decoding*: if *`encoding`* and/or *`errors`* are passed, this will decode the object, which can either be a byte string or a character buffer, using the codec for *`encoding`*. The *`encoding`* parameter is a string giving the name of a Unicode encoding; if the encoding is not known, `LookupError` is raised. Error handling is done according to *`errors`*, which may be `'strict'` (the default), to raise `ValueError` on encoding errors; `'ignore'`, to silently ignore errors and potentially lose data; or `'replace'`, to replace input characters that cannot be decoded with the official Unicode replacement character, `U+FFFD`. See also the standard library's `codecs` module, and the similar `bytes.decode()`

method (e.g., `b'a\xe4'.decode('latin-1')` is equivalent to `str(b'a\xe4', 'latin-1')`).

In Python 2.X, this call has simpler signature `str([object])`, and returns a string containing the higher-level printable representation of *`object`* (equivalent to the first Python 3.X usage mode given in the preceding list's first bullet item). Unicode decoding is implemented in 2.X by string methods or the 2.X `unicode()` call, which is essentially the same as the 3.X `str()` here (see the next section).

`sum(`*`iterable`*`[, `*`start`*`])`
: Sums *`start`* and all the items of any *`iterable`*, and returns the total. *`start`* defaults to `0`. The iterable's items are normally numbers and are not allowed to be strings. Hint: to concatenate an iterable of strings, use `''.join(`*`iterable`*`)`.

`super([`*`type`*`[, `*`object`*`]])`
: Returns the superclass of *`type`*. If the second argument is omitted, the super object returned is unbound. If the second argument is an object, `isinstance(`*`object, type`*`)` must be true. If the second argument is a type, `issubclass(`*`object, type`*`)` must be true. This call works for all classes in 3.X, but only for new-style classes in Python 2.X, where *`type`* is also not optional.

  In 3.X only, calling `super()` without arguments in a class method is implicitly equivalent to `super(`*`containing-class, method-self-argument`*`)`. Whether implicit or explicit, this call form creates a bound proxy object that pairs the *`self`* instance with access to the calling class's location on the MRO of *`self`*'s class. This proxy object is usable for later superclass attribute references and method calls. See also "New-style classes: MRO" for more on MRO ordering.

  Because `super()` always selects a *next* class on the MRO—the first class following the calling class having a requested attribute, whether it is a true superclass or not—it can be used for method call routing. In a *single-inheritance* class tree, this call may be used to refer to parent superclasses

generically without naming them explicitly. In *multiple-inheritance* trees, this call can be used to implement cooperative method-call dispatch that propagates calls through a tree.

The latter usage mode, cooperative method-call dispatch, may be useful in diamonds, as a conforming method call chain visits each superclass just once. However, `super()` can also yield highly implicit behavior which for some programs may not invoke superclasses as expected or required. The `super()` method dispatch technique generally imposes three requirements:

- *Anchors*: the method called by `super()` must exist—which requires extra code if no call-chain anchor is present.
- *Arguments*: the method called by `super()` must have the same argument signature across the entire class tree—which can impair flexibility, especially for implementation-level methods like constructors.
- *Deployment*: every appearance of the method called by `super()` but the last must use `super()` itself—which can make it difficult to use existing code, change call ordering, override methods, and code self-contained classes.

Because of these constraints, calling superclass methods by explicit superclass name instead of using `super()` may in some cases be simpler, more predictable, or required. For a superclass `S`, the explicit and traditional form `S.method(self)` is equivalent to the implicit `super().method()`. See also "New-style inheritance algorithm" for more on the `super()` attribute lookup special case; instead of running full inheritance, its result objects scan a context-dependent tail portion of a class tree's MRO, selecting the first matching descriptor or value.

`tuple([iterable])`
: Returns a new tuple with the same elements as any *`iterable`* passed in. If *`iterable`* is already a tuple, it is returned directly (not a copy); this suffices because tuples are immutable. If no argument, returns a new empty tuple. This is also a subclassable type class name.

`type(object | (name, bases, dict))`
: This call (which is also a subclassable type name) is used in two different modes, determined by call pattern:

- *With one argument*, returns a type object representing the type of *`object`*. Useful for type testing in `if` statements (e.g., `type(X)==type([])`). See also module `types` in the standard library for preset type objects that are not built-in names, and `isinstance()` earlier in this section. In new-style classes, `type(object)` is generally the same as *`object`*`.__class__`. In Python 2.X only, the `types` module also includes synonyms for most built-in type names.
- *With three arguments*, serves as a constructor, returning a new type object. This is 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 (super) classes and becomes the `__bases__` attribute; and the *`dict`* dictionary is the namespace containing attribute definitions for the class body and becomes the `__dict__` attribute. For example, the following are equivalent:

```
class X(object): a = 1
X = type('X', (object,), dict(a=1))
```

  This mapping is employed for *metaclass* construction, in which such `type()` calls are issued automatically, and generally invoke a metaclass's `__new__()` and/or `__init__()` with class creation arguments, for subclasses of `type`.

See also "Metaclasses", "Class decorators in Python 3.X, 2.6, and 2.7", and `__new__()` in "Operator Overloading Methods".

`vars([`*`object`*`])`
: Without arguments, returns a dictionary containing the current local scope's names. With a module, class, or class instance *`object`* as an argument, it returns a dictionary corresponding to *`object`*'s attribute namespace (i.e., its `__dict__`). The result should not be modified. Hint: useful for referring to variables in string formatting.

`zip([`*`iterable`*`[, `*`iterable`*`]*])`
: Returns a series of tuples, where each $i^{th}$ tuple contains the $i^{th}$ element from each of the argument iterables. For example, `zip('ab', 'cd')` returns `('a', 'c')` and `('b', 'd')`. At least one iterable is required, or the result is empty. The result series is truncated to the length of the shortest argument iterable. With a single iterable argument, it returns a series of one-tuples. May also be used to unzip zipped tuples: `X, Y = zip(*zip(T1, T2))`.

  In Python 2.X, this returns a *list*. In Python 3.X, it returns an *iterable* object that generates values on demand and can be traversed only once (wrap in a `list()` call to force results generation if required). In Python 2.X (but not Python 3.X), when there are multiple argument iterables of the same length, `zip()` is similar to `map()` with a first argument of `None`.

## Python 2.X Built-in Functions

The preceding section notes semantic differences between built-in functions that are available in *both* Python 3.X and 2.X. This section notes content differences in the two lines.

### Python 3.X built-ins not supported by Python 2.X

Python 2.X does not generally have the following Python 3.X built-in functions:

`ascii()`
: This works like Python 2.X's `repr()`.

`exec()`
: This is a statement form in Python 2.X with similar semantics.

`memoryview()`
: But made available in Python 2.7 for 3.X compatibility.

`print()`
: Present in Python 2.X's `__builtin__` module, but not directly usable syntactically without `__future__` imports, as printing is a statement form and reserved word in Python 2.X (see "The print Statement").

## Python 2.X built-ins not supported by Python 3.X

Python 2.X has the following additional built-in functions, some of which are available in different forms in Python 3.X:

`apply(`*`func`*`,` *`pargs`* `[,` *`kargs`*`])`
: Calls any callable object *`func`* (a function, method, class, etc.), passing the positional arguments in tuple *`pargs`*, and the keyword arguments in dictionary *`kargs`*. It returns the *`func`* call result.

  In Python 3.X, this is removed. Use the argument-unpacking call syntax instead: *`func`*`(*`*`pargs`*`, **`*`kargs`*`)`. This starred form is also preferred in Python 2.X, both because it is more general and because it is symmetric with function definitions' starred terms (see "The Expression Statement").

`basestring()`
: The base (super) class for normal and Unicode strings (useful for `isinstance()` tests).

  In Python 3.X, the single `str` type represents all text (both 8-bit and richer Unicode).

`buffer(`*`object`*`[, `*`offset`*`[, `*`size`*`]])`
: Returns a new buffer object for a conforming *`object`* (see the Python 2.X Library Reference).

  This call is removed in Python 3.X. The new `memoryview()` built-in provides similar functionality in 3.X, and is also available in Python 2.7 for forward compatibility.

`cmp(`*`X`*`, `*`Y`*`)`
: Returns a negative integer, zero, or a positive integer to designate *`X`*`<`*`Y`*, *`X`*`==`*`Y`*, or *`X`*`>`*`Y`*, respectively.

  In Python 3.X, this is removed, but may be simulated as: `(`*`X`*`>`*`Y`*`) - (`*`X`*`<`*`Y`*`)`. However, most common `cmp()` use cases (comparison functions in sorts, and the `__cmp__()` method of classes) have also been removed in Python 3.X.

`coerce(`*`X`*`, `*`Y`*`)`
: Returns a tuple containing the two numeric arguments *`X`* and *`Y`* converted to a common type.

  This call is removed in Python 3.X. (Its main use case was for Python 2.X classic classes.)

`execfile(`*`filename`*`[, `*`globals`*`[, `*`locals`*`]])`
: Like `eval()`, but runs all the code in a file whose string name is passed in as *`filename`* (instead of an expression). Unlike imports, this does not create a new module object for the file. It returns `None`. Namespaces for code in *`filename`* are as for `eval()`.

  In Python 3.X, this may be simulated as: `exec(open(`*`filename`*`).read())`.

`file(`*`filename`*`[, `*`mode`*`[, `*`bufsize`*`]])`
: An alias for the `open()` built-in function, and the subclassable class name of the built-in file type.

  In Python 3.X, the name `file` is removed: use `open()` to access files, and the `io` standard library module to customize them (`io` is used by `open()` in 3.X, and is an option in 2.X as of 2.6).

`input([prompt])` (original 2.X form)
: Prints *prompt*, if given. Then it reads an input line from the *stdin* stream (`sys.stdin`), evaluates it as Python code, and returns the result. In 2.X, this is like `eval(raw_input(prompt))`. Hint: do not use this to evaluate untrustworthy code strings, as they run as program code.

  In Python 3.X, because `raw_input()` was renamed `input()`, the original Python 2.X `input()` is no longer available, but may be simulated as: `eval(input(prompt))`.

`intern(string)`
: Enters *string* in the table of "interned strings" and returns the interned string. Interned strings are "immortals" and serve as a performance optimization. (They can be compared by fast `is` identity, rather than == equality.)

  In Python 3.X, this call has been moved to `sys.intern()`. Import module `sys` to use it, and see "The sys Module" for more details.

`long(X[, base])`
: Converts a number or a string *X* to a long integer. *base* can be passed only if *X* is a string. If `0`, the base is determined by the string contents; otherwise, it is used for the base of the conversion. This is a subclassable type class name.

  In Python 3.X, the `int` integer type supports arbitrarily long precision, and so subsumes Python 2.X's `long` type. Use `int()` in Python 3.X.

`raw_input([prompt])`
: This is the Python 2.X name of the Python 3.X `input()` function described in the preceding section: prints *prompt*, reads and returns, but does not evaluate, the next input line.

  In Python 3.X, use the `input()` built-in.

`reduce(func, iterable[, init])`
: Applies the two-argument function *func* to successive items from *iterable*, so as to reduce the collection to a single value. If *init* is given, it is prepended to *iterable*.

In Python 3.X, this built-in is still available, as `functools.reduce()`. Import module `functools` to use it.

`reload(`*`module`*`)`
: Reloads, reparses, and reexecutes an already imported *`module`* in the module's current namespace. Reexecution replaces prior values of the module's attributes in-place. *`module`* must reference an existing module object; it is not a new name or a string. This is useful in interactive mode if you want to reload a module after fixing it, without restarting Python. It returns the *`module`* object. See also the `sys.modules` table, where imported modules are retained (and can be deleted to force reimports).

  In Python 3.X, this built-in is still available as `imp.reload()`. Import module `imp` to use it.

`unichr(`*`I`*`)`
: Returns the Unicode string of one character whose Unicode code point is integer *`I`* (e.g., `unichr(97)` returns string `u'a'`). This is the inverse of `ord()` for Unicode strings, and the Unicode version of `chr()`. The argument must be in range `0`...`65,535` inclusive, or `ValueError` is raised.

  In Python 3.X, normal strings represent Unicode characters: use the `chr()` call instead (e.g., `ord('\xe4')` is `228`, and `chr(228)` and `chr(0xe4)` both return `'ä'`).

`unicode([`*`object`*`[,`*`encoding`*`[,`*`errors`*`]]])`
: Works similarly to the 3.X `str()` function (see `str()` in the preceding section for more details). With just *one* argument, this returns a high-level print string representation for *`object`*, but as a 2.X Unicode string (not a *`str`*). With *more than one* argument, this performs Unicode decoding of string *`object`* using the codec for *`encoding`*, with error handling performed according to *`errors`*. The error handling default is strict errors mode, where all encoding errors raise `ValueError`.

  See also the `codecs` module in the Python Library Reference for files that support encodings. In 2.X, objects may provide

a `__unicode__()` method that gives their Unicode string for `unicode(X)`.

In Python 3.X, there is no separate type for Unicode—the `str` type represents all text (both 8-bit and richer Unicode), and the `bytes` type represents bytes of 8-bit binary data. Use normal `str` strings for Unicode text; `bytes.decode()` or `str()` to decode from raw bytes to Unicode according to an encoding; and normal `open()` file objects to process Unicode text files.

`xrange([`*`start`*`,] `*`stop`*` [, `*`step`*`])`
: Like `range()`, but doesn't actually store the entire list all at once (rather, it generates one integer at a time). This is useful in `for` loops when there is a big range and little memory. It optimizes space, but generally has no speed benefit.

  In Python 3.X, the original `range()` function is changed to return an iterable instead of producing a result list in memory, and thus subsumes and Python 2.X's `xrange()`, which is removed.

In addition, the file `open()` call has changed radically enough in Python 3.X that individual mention of Python 2.X's variant is warranted here (in Python 2.X, `codecs.open()` has many of the features in Python 3.X's `open()`, including support for Unicode encoding translations on transfers):

`open(`*`filename`*` [, `*`mode`*`, [`*`bufsize`*`]])`
: Returns a new `file` object connected to the external file named *`filename`* (a string), or raises `IOError` if the open fails. The file name is mapped to the current working directory, unless it includes a directory path prefix. The first two arguments are generally the same as those for C's `fopen()` function, and the file is managed by the `stdio` system. With `open()`, file data is always represented as a normal `str` string in your script, containing bytes from the file. (`codecs.open()` interprets file content as encoded Unicode text, represented as `unicode` objects.)

*mode* defaults to `'r'` if omitted, but can be `'r'` for input; `'w'` for output (truncating the file first); `'a'` for append; and `'rb'`, `'wb'`, or `'ab'` for binary files (to suppress line-end conversions to and from `\n`). On most systems, modes can also have a `+` appended to open in input/output updates mode (e.g., `'r+'` to read/write, and `'w+'` to read/write but initialize the file to empty).

*bufsize* defaults to an implementation-dependent value, but can be `0` for unbuffered, `1` for line-buffered, negative for system-default, or a given specific size. Buffered data transfers might not be immediately fulfilled (use file object `flush()` methods to force). See also the `io` module in Python's standard library: an alternative to `file` in 2.X, and the normal file interface for `open()` in 3.X.

# Built-in Exceptions

This section describes exceptions predefined by Python that may be raised by Python or user code during a program's execution. It primarily presents the state of built-in exceptions in Python 3.3—which introduces new classes for system-related errors that subsume prior generic classes with state information—but gives details common to most Python versions. See the Python 3.2 and 2.X subsections at the end of this section for version-specific differences.

Beginning with Python 1.5, all built-in exceptions are *class objects* (prior to 1.5 they were strings). Built-in exceptions are provided in the built-in scope namespace (see "Namespace and Scope Rules"), and many built-in exceptions have associated state information that provides exception details. User-defined exceptions are generally derived from this built-in set (see "The raise Statement").

## Superclasses: Categories

The following exceptions are used only as superclasses for other exceptions:

`BaseException`
: The root superclass for all built-in exceptions. It is not meant to be directly inherited by user-defined classes; use `Exception` for this role instead. If `str()` is called on an instance of this class, the representation of the constructor argument(s) passed when creating the instance are returned (or the empty string if there were no such arguments). These instance constructor arguments are stored and made available in the instance's `args` attribute as a tuple. Subclasses inherit this protocol.

`Exception`
: The root superclass for all built-in and non-system-exiting exceptions. This is a direct subclass of `BaseException`.

  All user-defined exceptions should be derived (inherit) from this class. This derivation is required for user-defined exceptions in Python 3.X; Python 2.6 and 2.7 require this of new-style classes, but also allow standalone exception classes.

  `try` statements that catch this exception will catch all but system exit events, because this class is superclass to all exceptions but `SystemExit`, `KeyboardInterrupt`, and `GeneratorExit` (these three derive directly from `BaseException` instead).

`ArithmeticError`
: Arithmetic error exceptions category: the superclass of `OverflowError`, `ZeroDivisionError`, and `FloatingPointError`, and a subclass of `Exception`.

`BufferError`
: Raised when a buffer-related operation cannot be performed. A subclass of `Exception`.

`LookupError`
: Sequence and mapping index errors: the superclass for `IndexError` and `KeyError`, also raised for some Unicode encoding lookup errors. A subclass of `Exception`.

`OSError` (Python 3.3 version)
: Raised when a system function triggers a system-related error, including I/O and file operation failures. As of Python 3.3, this exception is a root class to a new set of descriptive system-related exceptions enumerated in "Specific OSError Exceptions", which subsume generic exceptions with state information used in 3.2 and earlier, described in "Python 3.2 Built-in Exceptions".

  In Python 3.3, `OSError` is a subclass of `Exception`, and includes common informational attributes that give system error details: `errno` (numeric code); `strerror` (string message); `winerror` (on Windows); and `filename` (for exceptions involving file paths). In 3.3, this class incorporates the former `EnvironmentError`, `IOError`, `WindowsError`, `VMSError`, `socket.error`, `select.error`, and `mmap.error`, and is a synonym to `os.error`. See the latter in "The os System Module" for additional attribute details.

## Specific Exceptions

The following classes are more specific exceptions that are actually raised. In addition, `NameError`, `RuntimeError`, `SyntaxError`, `ValueError`, and `Warning` are both specific exceptions and category superclasses to other built-in exceptions:

`AssertionError`
: Raised when an `assert` statement's test is false.

`AttributeError`
: Raised on attribute reference or assignment failure.

`EOFError`
: Raised when the immediate end-of-file is hit by `input()` (or `raw_input()` in Python 2.X). File object read methods return an empty object at end of file instead of raising this.

`FloatingPointError`
: Raised on floating-point operation failure.

`GeneratorExit`
: Raised when a generator's `close()` method is called. This directly inherits from `BaseException` instead of `Exception` since it is not an error.

`ImportError`
: Raised when an `import` or `from` fails to find a module or attribute. As of Python 3.3, instances include `name` and `path` attributes identifying the module that triggered the error, passed as keyword arguments to the constructor.

`IndentationError`
: Raised when improper indentation is found in source code. Derived from `SyntaxError`.

`IndexError`
: Raised on out-of-bounds sequence offsets (fetch or assign). Slice indexes are silently adjusted to fall in the allowed range; if an index is not an integer, `TypeError` is raised.

`KeyError`
: Raised on references to nonexistent mapping keys (fetch). Assignment to a nonexistent key creates that key.

`KeyboardInterrupt`
: Raised on user entry of the interrupt key (normally Ctrl-C or Delete). During execution, a check for interrupts is made regularly. This exception inherits directly from `BaseException` to prevent it from being accidentally caught by code that catches `Exception` and thus prevents interpreter exit.

`MemoryError`
: Raised on recoverable memory exhaustion. This causes a stack-trace to be displayed if a runaway program was its cause.

`NameError`
: Raised on failures to find a local or global unqualified name.

`NotImplementedError`
: Raised on failures to define expected protocols. Abstract class methods may raise this when they require a method to be redefined. Derived from `RuntimeError`. (This is not to be confused with `NotImplemented`, a special built-in object returned by some operator-overloading methods when operand types are not supported; see "Operator Overloading Methods".)

`OverflowError`
: Raised on excessively large arithmetic operation results. This cannot occur for integers as they support arbitrary precision. Due to constraints in the underlying C language, most floating-point operations are also not checked for overflow.

`ReferenceError`
: Raised in conjunction with *weak references*: tools for maintaining references to objects which do not prevent their reclamation (e.g., caches). See the `weakref` module in the Python standard library.

`RuntimeError`
: A rarely used catch-all exception.

`StopIteration`
: Raised at the end of values progression in iterator objects. Raised by the `next(`*`I`*`)` built-in and *`I`*`.__next__()` methods (named *`I`*`.next()` in Python 2.X).

  As of Python 3.3, instances include a `value` attribute, which either reflects an explicit constructor positional argument, or is automatically set to the return value given in a generator

function's `return` statement that ends its iteration. This value defaults to `None`, is also available in the exception's normal `args` tuple, and is unused by automatic iterations. Because generator functions must return *no* value prior to 3.3 (and generate syntax errors if they try), use of this extension is not compatible with earlier 2.X and 3.X versions. See also "The yield Statement".

`SyntaxError`
: Raised when parsers encounter a syntax error. This may occur during import operations, calls to `eval()` and `exec()`, and when reading code in a top-level script file or standard input. Instances of this class have attributes `filename`, `lineno`, `offset`, and `text` for access to details; `str()` of the exception instance returns only the basic message.

`SystemError`
: Raised on interpreter internal errors that are not serious enough to shut down (these should be reported).

`SystemExit`
: Raised on a call to `sys.exit(`*`N`*`)`. If not handled, the Python interpreter exits, and no stack traceback is printed. If the passed value *`N`* is an integer, it specifies the program's system exit status (passed on to C's exit function); if it is `None` or omitted, the exit status is `0` (success); if it has another type, the object's value is printed and the exit status is `1` (failure). Derived directly from `BaseException` to prevent it from being accidentally caught by code that catches `Exception` and thus prevents interpreter exit. See also `sys.exit()` in "The sys Module".

  `sys.exit()` raises this exception so that clean-up handlers (`finally` clauses of `try` statements) are executed, and so that a debugger can execute a script without losing control. The `os._exit()` function exits immediately when needed (e.g., in the child process after a call to `fork()`). Also see the `atexit` module in the standard library for exit function specification.

`TabError`
: Raised when an improper mixture of spaces and tabs is found in source code. Derived from `IndentationError`.

`TypeError`
: Raised when an operation or function is applied to an object of inappropriate type.

`UnboundLocalError`
: Raised on references to local names that have not yet been assigned a value. Derived from `NameError`.

`UnicodeError`
: Raised on Unicode-related encoding or decoding errors; a superclass category, and a subclass of `ValueError`. Hint: some Unicode tools may also raise `LookupError`.

`UnicodeEncodeError`

`UnicodeDecodeError`

`UnicodeTranslateError`
: Raised on Unicode-related processing errors; subclasses of `UnicodeError`.

`ValueError`
: Raised when a built-in operation or function receives an argument that has the correct type but an inappropriate value, and the situation is not described by a more specific exception like `IndexError`.

`ZeroDivisionError`
: Raised on division or modulus operations with value `0` as the right-side operand.

## Specific OSError Exceptions

Available in Python 3.3 and later, the following subclasses of `OSError` identify system errors, and correspond to system error codes available in `EnvironmentError` in earlier Pythons (see "Python 3.2 Built-in Exceptions"). See also `OSError` in

"Superclasses: Categories" for informational attributes common to its subclasses here:

`BlockingIOError`
: Raised when an operation would block on an object set for nonblocking operation. Has additional attribute `characters_written`, the number of characters written to the stream before it blocked.

`ChildProcessError`
: Raised when an operation on a child process failed.

`ConnectionError`
: Superclass for connection-related exceptions `BrokenPipeError`, `ConnectionAbortedError`, `ConnectionRefusedError`, and `ConnectionResetError`.

`BrokenPipeError`
: Raised when trying to write on a pipe while the other end has been closed, or trying to write on a socket that has been shut down for writing.

`ConnectionAbortedError`
: Raised when a connection attempt is aborted by the peer.

`ConnectionRefusedError`
: Raised when a connection attempt is refused by the peer.

`ConnectionResetError`
: Raised when a connection is reset by the peer.

`FileExistsError`
: Raised when trying to create a file or directory which already exists.

`FileNotFoundError`
: Raised when a file or directory is requested but doesn't exist.

`InterruptedError`
: Raised when a system call is interrupted by an incoming signal.

`IsADirectoryError`
: Raised when a file operation such as `os.remove()` is requested on a directory.

`NotADirectoryError`
: Raised when a directory operation such as `os.listdir()` is requested on a nondirectory.

`PermissionError`
: Raised for operations run without adequate access rights (e.g., file system permissions).

`ProcessLookupError`
: Raised when a process doesn't exist.

`TimeoutError`
: Raised when a system function times out at the system level.

## Warning Category Exceptions

The following exceptions are used as warning categories:

`Warning`
: The superclass for all of the following warnings; a direct subclass of `Exception`.

`UserWarning`
: Warnings generated by user code.

`DeprecationWarning`
: Warnings about deprecated features.

`PendingDeprecationWarning`
: Warnings about features that will be deprecated in the future.

`SyntaxWarning`
: Warnings about dubious syntax.

`RuntimeWarning`
: Warnings about dubious runtime behavior.

`FutureWarning`
: Warnings about constructs that will change semantically in the future.

`ImportWarning`
: Warnings about probable mistakes in module imports.

`UnicodeWarning`
: Warnings related to Unicode.

`BytesWarning`
: Warnings related to `bytes` and buffer (memory-view) objects.

`ResourceWarning`
: Added as of Python 3.2, the superclass for warnings related to resource usage.

## Warnings Framework

Warnings are issued when future language changes might break existing code in a future Python release, and in other contexts. Warnings may be configured to print messages, raise exceptions, or be ignored. The warnings framework can be used to issue warnings by calling the `warnings.warn()` function:

```
warnings.warn("usage obsolete", DeprecationWarning)
```

In addition, you can add filters to disable certain warnings. You can apply a regular expression pattern to a message or module name to suppress warnings with varying degrees of generality. For example, you can suppress a warning about the use of the deprecated `regex` module by calling:

```
import warnings
warnings.filterwarnings(action = 'ignore',
                        message='.*regex module*',
                        category=DeprecationWarning,
                        module = '__main__')
```

This adds a filter that affects only warnings of the class `DeprecationWarning` triggered in the `__main__` module, applies a

regular expression to match only the message that names the `regex` module being deprecated, and causes such warnings to be ignored. Warnings can also be printed only once, printed every time the offending code is executed, or turned into exceptions that will cause the program to stop (unless the exceptions are caught). See the `warnings` module documentation in Python's manual (version 2.1 and later) for more information. See also the `-W` argument in "Python Command Options".

## Python 3.2 Built-in Exceptions

In Python 3.2 and earlier, the following additional exceptions are available. As of Python 3.3, they have been merged into `OSError`. They are retained in 3.3 for compatibility, but may be removed in future releases:

`EnvironmentError`
: The category for exceptions that occur outside Python: the superclass for `IOError` and `OSError`, and a subclass of `Exception`. The raised instance includes informational attributes `errno` and `strerror` (and possible `filename` for exceptions involving file paths), which are also in `args`, and give system error code and message details.

`IOError`
: Raised on I/O or file-related operation failures. Derived from `EnvironmentError` with state information described earlier in this list.

`OSError` (Python 3.2 version)
: Raised on `os` module errors (its `os.error` exception). Derived from `EnvironmentError` with state information described earlier in this list.

`VMSError`
: Raised on VMS-specific errors; a subclass of `OSError`.

`WindowsError`
: Raised on Windows-specific errors; a subclass of `OSError`.

## Python 2.X Built-in Exceptions

The set of available exceptions, as well as the shape of the exception class hierarchy, varies slightly in Python 2.X from the 3.X description of the preceding sections. For example, in Python 2.X:

- `Exception` is the topmost root class (not `BaseException`, which is absent in Python 2.X).
- `StandardError` is an additional `Exception` subclass, and is a root class above all built-in exceptions except `SystemExit`.

See Python 2.X library manuals for full details for your version.

# Built-in Attributes

Some objects export special attributes that are predefined by Python. The following is a partial list because many types have unique attributes all their own; see the entries for specific types in the Python Library Reference:[5]

*X*`.__dict__`
: Dictionary used to store object *X*'s writable (changeable) attributes.

*I*`.__class__`
: Class object from which instance *I* was generated. In version 2.2 and later, this also applies to types, and most objects have a `__class__` attribute (e.g., `[].__class__ == list == type([])`).

5. As of Python 2.1, you can also attach arbitrary user-defined attributes to *function* objects, simply by assigning them values; see "Function defaults and attributes". Python 2.X also supports special attributes *I*`.__methods__` and *I*`.__members__`: lists of method and data member names for instances of some built-in types. These are removed in Python 3.X; use the built-in `dir()` function.

`C.__bases__`
: Tuple of class *C*'s base classes, as listed in *C*'s class statement header.

`C.__mro__`
: The computed MRO path through new-style class *C*'s tree (see "New-style classes: MRO").

*X*`.__name__`
: Object *X*'s name as a string; for classes, the name in the statement header; for modules, the name as used in imports, or `"__main__"` for the module at the top level of a program (e.g., the main file run to launch a program).

# Standard Library Modules

Standard library modules are always available but must be imported to be used in client modules. To access them, use one of these formats:

- `import` *`module`*, and fetch attribute names (*`module.name`*)
- `from` *`module`* `import` *`name`*, and use module names unqualified (*`name`*)
- `from` *`module`* `import *`, and use module names unqualified (*`name`*)

For instance, to use name `argv` in the `sys` module, either use `import sys` and name `sys.argv` or use `from sys import argv` and name `argv`. The former full form—*`module.name`*—is used in content list headers here only to provide context in multipage listings; descriptions often use just *`name`*.

There are hundreds of standard library modules, all of which are at least as prone to change as the language itself. Accordingly, the following sections *are not exhaustive*, and generally document only commonly used names in commonly used modules. See Python's Library Reference for a more complete reference to standard library modules.

In all of the following module sections:

- Listed export names followed by parentheses are *functions* that must be called; others are simple attributes (i.e., variable names in modules that are fetched, not called).
- Module contents document the modules' state in *Python 3.X*, but generally apply to both 3.X and 2.X except as noted; see Python manuals for further information on version-specific differences.

# The sys Module

The `sys` module contains *interpreter-related tools*: items related to the interpreter or its process in both Python 3.X and 2.X. It also provides access to some environment components, such as the command line, standard streams, and so on. See also `os` in "The os System Module" for additional process-related tools:

`sys.argv`
: Command-line argument strings list: [*`scriptname`*`,` *`arguments`*`...`]. Similar to C's `argv` array. `argv[0]` is either the script file's name (possibly with a full path); the string `'-c'` for the `-c` command-line option; a module's path name for the `-m` option; `'-'` for the – option; or the empty string if no script name or command option was passed. See also "Command-Line Program Specification".

`sys.byteorder`
: Indicates the native byte order (e.g., `'big'` for big-endian, `'little'` for little-endian).

`sys.builtin_module_names`
: Tuple of string names of C modules compiled into this Python interpreter.

`sys.copyright`
: String containing the Python interpreter copyright.

`sys.displayhook(value)`
: Called by Python to display result values in interactive sessions; assign `sys.displayhook` to a one-argument function to customize output.

`sys.dont_write_bytecode`
: While this is true, Python won't try to write *.pyc* or *.pyo* files on the import of source modules (see also `-B` command-line option in "Python Command-Line Usage" to select at launch).

`sys.excepthook(type, value, traceback)`
: Called by Python to display uncaught exception details to *stderr*; assign `sys.excepthook` to a three-argument function to customize exception displays.

`sys.exc_info()`
: Returns tuple of three values describing the exception currently being handled: (*`type`*, *`value`*, *`traceback`*), where *`type`* is the exception class, *`value`* is the instance of the exception class raised, and *`traceback`* is an object that gives access to the runtime call stack as it existed when the exception occurred. Specific to current thread. Subsumes `exc_type`, `exc_value`, and `exc_traceback` in Python 1.5 and later (all three of which are present in earlier Python 2.X, but removed completely in Python 3.X). See the `traceback` module in the Python Library Reference for processing traceback objects, and "The try Statement" for more on exceptions.

`sys.exec_prefix`
: Assign to a string giving the site-specific directory prefix where the platform-dependent Python files are installed; defaults to */usr/local* or a build-time argument. Used to locate shared library modules (in *<exec_prefix>/lib/python<version>/lib-dynload*) and configuration files.

`sys.executable`
: String giving the full file pathname of the Python interpreter program running the caller.

`sys.exit([N])`
: Exits from a Python process with status *N* (default `0`) by raising a `SystemExit` built-in exception (which can be caught in a `try` statement and ignored if needed). See also `SystemExit` in ("Built-in Exceptions") for more usage details, and the `os._exit()` function (in "The os System Module") for a related tool that exits immediately without exception processing (useful in child processes after an `os.fork()`). Also see the `atexit` module in the Python standard library for general exit function specification.

`sys.flags`
: Values of Python command-line options, one attribute per option (see Python manuals).

`sys.float_info`
: Details of Python floating-point implementation via attributes (see Python manuals).

`sys.getcheckinterval()`
: In Python 3.1 and earlier, returns the interpreter's "check interval" (see `setcheckinterval()` later in this list). Superseded in Python 3.2 and later by `getswitchinterval()`.

`sys.getdefaultencoding()`
: Returns the name of the current default string encoding used by the Unicode implementation.

`sys.getfilesystemencoding()`
: Returns the name of the encoding used to convert Unicode filenames into system file names, or `None` if the system default encoding is used.

`sys._getframe([depth])`
: Returns a frame object from the Python call stack (see the Python Library Reference).

`sys.getrefcount(object)`
: Returns *object*'s current reference count value (+1 for the call's argument itself).

`sys.getrecursionlimit()`
: Returns the maximum depth limit of the Python call stack; see also `setrecursionlimit()`, later in this list.

`sys.getsizeof(`*`object`*`[, `*`default`*`])`
: Returns the size of an *`object`* in bytes. The object can be any type of object. All built-in objects return correct results, but third-party extension results are implementation specific. *`default`* provides a value that will be returned if the object type does not implement the size retrieval interface.

`sys.getswitchinterval()`
: In Python 3.2 and later, returns the interpreter's current thread switch interval setting (see `setswitchinterval()` later in this list). In Python 3.1 and earlier, use `getcheck interval()`.

`sys.getwindowsversion()`
: Return an object describing the Windows version currently running (see Python manuals).

`sys.hexversion`
: Python version number, encoded as a single integer (perhaps best viewed with the `hex()` built-in function). Increases with each new release.

`sys.implementation`
: Available as of Python 3.3, an object giving information about the implementation of the currently running Python interpreter (name, version, etc.). See Python manuals.

`sys.int_info`
: Details of Python integer implementation via attributes (see Python manuals).

`sys.intern(`*`string`*`)`
: Enters *`string`* in the table of "interned" strings and returns the interned string—the string itself or a copy. Interning strings provides a small performance improvement for dictionary lookup: if both the keys in a dictionary and the lookup key are interned, key comparisons (after hashing)

can be done by comparing pointers instead of strings. Normally, names used in Python programs are automatically interned, and the dictionaries used to hold module, class, and instance attributes have interned keys.

`sys.last_type`, `sys.last_value`, `sys.last_traceback`
: Type, value, and traceback objects of last uncaught exception (mostly for postmortem debugging).

`sys.maxsize`
: An integer giving the maximum value a variable of type `Py_ssize_t` can take. It's usually `2**31 - 1` on a 32-bit platform and `2**63 - 1` on a 64-bit platform.

`sys.maxunicode`
: An integer giving the largest supported code point for a Unicode character. In Python 3.3 and later, this is always `1114111` (`0x10FFFF` in hexadecimal) due to 3.3's flexible and variable-size string storage system. Prior to 3.3, the value of this depends on the configuration option that specifies whether Unicode characters are stored as UCS-2 or UCS-4, and may be `0xFFFF` or `0x10FFFF`.

`sys.modules`
: Dictionary of modules that are already loaded; there is one *`name:object`* entry per module. Hint: this dictionary may be changed to impact future imports (e.g., `del sys.modules['`*`name`*`']` forces a module to be reloaded on next import).

`sys.path`
: List of strings specifying module import search path. Initialized from `PYTHONPATH` shell variable, any *.pth* path files, and any installation-dependent defaults. Hint: this attribute and its list may both be changed to impact future imports (e.g., `sys.path.append('C:\\dir')` adds a directory to the module search path dynamically).

  The first item, `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 working directory first. The script directory is inserted before the entries inserted from `PYTHONPATH`. See also "The import Statement".

`sys.platform`
: String identifying the system on which Python is running: `'win32'`, `'darwin'`, `'linux2'`, `'cygwin'`, `'os2'`, `'freebsd8'`, `'sunos5'`, `'PalmOS3'`, etc. Useful for tests in platform-dependent code.

  This is `'win32'` for all current flavors of Windows, but test `sys.platform[:3]=='win'` or `sys.platform.startswith('win')` for generality. As of Python 3.3, all Linux platforms are `'linux'`, but scripts should similarly test for this with *`str`*`.startswith('linux')` as it was formerly either `'linux2'` or `'linux3'`.

`sys.prefix`
: Assign to a string giving the site-specific directory prefix, where platform-independent Python files are installed; defaults to */usr/local* or a build-time argument. Python library modules are installed in the directory *<prefix>/lib/python<version>*; platform-independent header files are stored in *<prefix>/include/python<version>*.

`sys.ps1`
: String specifying primary prompt in interactive mode; defaults to `>>>` unless assigned.

`sys.ps2`
: String specifying secondary prompt for compound statement continuations, in interactive mode; defaults to `...` unless assigned.

`sys.setcheckinterval(`*`reps`*`)`
: Superseded in Python 3.2 and later by `setswitchinterval()` (covered in this list). In 3.2 and later, this function is still

present but has no effect, as the implementation of thread switching and asynchronous tasks was rewritten.

In Python 3.1 and earlier, called to set how often the interpreter checks for periodic tasks (e.g., thread switches, signal handlers) to *reps*, measured in virtual machine instructions (default is `100`). In general, a Python statement translates to multiple virtual machine instructions. Lower values maximize thread responsiveness but also maximize thread switch overhead.

`sys.setdefaultencoding(`*`name`*`)`
Removed as of Python 3.2. Call to set the current default string encoding used by the Unicode implementation to *name*. Intended for use by the `site` module and is available during start-up only.

`sys.setprofile(`*`func`*`)`
Call to set the system profile function to *func*: the profiler's "hook" (not run for each line). See the Python Library Reference for details.

`sys.setrecursionlimit(`*`depth`*`)`
Call to set maximum depth of the Python call stack to *depth*. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python. The default is `1,000` on Windows, but this may vary. Higher values may be required for deeply recursive functions.

`sys.setswitchinterval(`*`interval`*`)`
In Python 3.2 and later, sets the interpreter's thread switch interval to *interval*, given in seconds This is a floating-point value (e.g., 0.005 is 5 milliseconds) that determines the ideal duration of the time slices allocated to concurrently running Python threads. The actual value can be higher, especially if long-running internal functions or methods are used, and the choice of thread scheduled at the end of the interval is made by the operating system. (The Python interpreter does not have its own scheduler.)

In Python 3.1 and earlier, use `setcheckinterval()` instead (covered in this list).

`sys.settrace(`*`func`*`)`
: Call to set the system trace function to *`func`*. This is the program location or state change callback "hook" used by debuggers, etc. See the Python Library Reference for details.

`sys.stdin`
: A preopened file object, initially connected to the standard input stream, *stdin*. Can be assigned to any object with `read` methods to reset input within a script (e.g., `sys.stdin = MyObj()`). Used for interpreter input, including the `input()` built-in function (and `raw_input()` in Python 2.X).

`sys.stdout`
: A preopened file object, initially connected to the standard output stream, *stdout*. Can be assigned to any object with `write` methods to reset output within a script (e.g., `sys.stdout=open('log', 'a')`). Used for some prompts and the `print()` built-in function (and `print` statement in Python 2.X). Use `PYTHONIOENCODING` to override the platform-dependent encoding if needed (see "Python Environment Variables"), and `-u` for unbuffered streams (see "Python Command Options").

`sys.stderr`
: A preopened file object, initially connected to the standard error stream, *stderr*. Can be assigned to any object with `write` methods to reset `stderr` within a script (e.g., `sys.stderr=`*`wrappedsocket`*). Used for interpreter prompts/errors.

`sys.__stdin__`, `sys.__stdout__`, `sys.__stderr__`
: Original values of `stdin`, `stderr`, and `stdout` at program start (e.g., for restores as a last resort; normally, when assigning to `sys.stdout`, etc., save the old value and restore it in a `finally` clause). Note: these can be `None` for GUI apps on Windows with no console.

`sys.thread_info`
: Details of Python's thread implementation via attributes; new in Python 3.3 (see Python manuals).

`sys.tracebacklimit`
: Maximum number of traceback levels to print on uncaught exceptions; defaults to `1,000` unless assigned.

`sys.sys.version`
: String containing the version number of the Python interpreter.

`sys.version_info`
: Tuple containing five version identification components: major, minor, micro, release level, and serial. For Python 3.0.1, this is `(3, 0, 1, 'final', 0)`. In recent releases only, this is a named tuple, whose components may be accessed as either tuple items or attribute names; for Python 3.3.0, this displays `sys.version_info(major=3, minor=3, micro=0, releaselevel='final', serial=0)`. See the Python Library Reference for more details.

`sys.winver`
: Version number used to form registry keys on Windows platforms (available only on Windows; see the Python Library Reference).

# The string Module

The `string` module defines constants and variables for processing *string objects*. See also "Strings" for more on the string template substitution and formatting tools `Template` and `Formatter` defined in this module.

## Functions and Classes

As of Python 2.0, most functions in this module are also available as *methods* of string objects; method-based calls are more efficient, are preferred in 2.X, and are the only option retained in 3.X. See "Strings" for more details and a list of all available string

methods not repeated here. Only items unique to the `string` module are listed in this section:

`string.capwords(s, sep=None)`
: Split the argument *s* into words using `s.split()`, capitalize each word using `s.capitalize()`, and join the capitalized words using `s.join()`. If the optional argument `sep` is absent or `None`, runs of whitespace characters are replaced by a single space, and leading and trailing whitespace is removed; otherwise `sep` is used to split and join the words.

`string.maketrans(from, to)`
: Returns a translation table suitable for passing to `bytes.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.

`string.Formatter`
: Class that allows creation of custom formatters using the same mechanism as the `str.format()` method, described in "String formatting method".

`string.Template`
: String template substitution class, described in "Template string substitution".

## Constants

`string.ascii_letters`
: The string `ascii_lowercase + ascii_uppercase`.

`string.ascii_lowercase`
: The string `'abcdefghijklmnopqrstuvwxyz'`; not locale-dependent and will not change.

`string.ascii_uppercase`
: The string `'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`; not locale-dependent and will not change.

`string.digits`
: The string `'0123456789'`.

`string.hexdigits`
: The string `'0123456789abcdefABCDEF'`.

`string.octdigits`
: The string `'01234567'`.

`string.printable`
: Combination of `digits`, `ascii_letters`, `punctuation`, and `whitespace`.

`string.punctuation`
: String of characters that are considered punctuation characters in the locale.

`string.whitespace`
: String containing space, tab, line feed, return, vertical tab, and form feed: `' \t\n\r\v\f'`.

# The os System Module

The `os` module is the primary *operating system* (OS) services interface in both Python 3.X and 2.X. It provides generic OS support and a standard, platform-independent set of OS utilities. The `os` module includes tools for environments, processes, files, shell commands, and much more. It also includes a nested submodule, `os.path`, which provides a portable interface to directory processing tools.

Scripts that use `os` and `os.path` for systems programming are generally *portable* across most Python platforms. However, some `os` exports are not available on all platforms (e.g., `os.fork()` is available on Unix and Cygwin, but not in the standard Windows version of Python). Because the portability of such calls can change over time, consult the Python Library Reference for platform details.

The following sections highlight commonly used tools in this module. *This is a partial list*: see Python's standard library manual for full details on the over 200 tools in this module on some

platforms, as well as platform and version differences omitted here. Subsections here reflect this large module's functional areas:

- *Administrative Tools*: module-related exports
- *Portability Constants*: directory and search-path constants
- *Shell Commands*: running command lines and files
- *Environment Tools*: execution environment and context
- *File Descriptor Tools*: processing files by their descriptors
- *File Pathname Tools*: processing files by their path names
- *Process Control*: creating and managing processes
- *The os.path Module*: directory path name-related services

See also these *related system modules* in Python's standard library, covered in Python manuals except as noted: `sys`—interpreter process tools (see "The sys Module"); `subprocess`—spawned command control (see "The subprocess Module"); `threading` and `queue`—multithreading tools (see "Threading Modules"); `socket`—networking and IPC (see "Internet Modules and Tools"); `glob`—filename expansion (e.g., `glob.glob('*.py')`); `tempfile`—temporary files; `signal`—signal handling; `multiprocessing`—threading-like API for processes; and `getopt`, `optparse`, and, in 3.2 and later, `argparse`—command-line processing.

## Administrative Tools

Following are some miscellaneous module-related exports:

`os.error`
: An alias for the built-in `OSError` exception: see "Built-in Exceptions". Raised for all `os` module-related errors. This exception has two attributes: `errno`, the numeric error code per POSIX (e.g., the value of the C `errno` variable); and `strerror`, the corresponding error message provided by the operating system, and as formatted by underlying C functions (e.g., by `perror()`, and as for `os.strerror()`). For

exceptions that involve a file pathname (e.g., `chdir()`, `unlink()`), the exception instance also contains the attribute `filename`, the filename passed in. See the module `errno` in the Python Library Reference for names of the error codes defined by the underlying OS.

`os.name`
: Name of OS-specific modules whose names are copied to the top level of `os` (e.g., `posix`, `nt`, `mac`, `os2`, `ce`, or `java`). See also `sys.platform` in section "The sys Module".

`os.path`
: Nested module for portable pathname-related utilities. For example, `os.path.split()` is a platform-independent directory name tool that performs appropriate platform-specific action.

## Portability Constants

This section describes *file portability tools*, for directory and search paths, line feeds, and more. They are automatically set to the appropriate value for the platform on which a script is running, and are useful for both parsing and constructing platform-dependent strings. See also "The os.path Module":

`os.curdir`
: String used to represent current directory (e.g., `.` for Windows and POSIX, `:` for Macintosh).

`os.pardir`
: String used to represent parent directory (e.g., `..` for POSIX, `::` for Macintosh).

`os.sep`
: String used to separate directories (e.g., `/` for Unix, `\` for Windows, or `:` for Macintosh).

`os.altsep`
: Alternative separator string or `None` (e.g., `/` for Windows).

`os.extsep`
: The character that separates the base filename from the extension (e.g., `.`).

`os.pathsep`
: Character used to separate search path components, as in the `PATH` and `PYTHONPATH` shell variable settings (e.g., `;` for Windows, `:` for Unix).

`os.defpath`
: Default search path used by `os.exec*p*` calls if there is no `PATH` setting in the shell.

`os.linesep`
: String used to terminate lines on current platform (e.g., `\n` for POSIX, `\r` for Mac OS, and `\r\n` for Windows). Not required writing lines in text mode files—use the file object's auto-translation of `'\n'` (see `open()` in "Built-in Functions").

`os.devnull`
: The file path of the "null" device (for text be discarded). This is `'/dev/null'` for POSIX, and `'nul'` for Windows (also in the `os.path` submodule).

## Shell Commands

These functions run *command lines or files* in the underlying operating system. In Python 2.X, this module has `os.popen2/3/4` calls, which have been replaced in Python 3.X by `subprocess.Popen`—a tool that generally offers finer-grained control over spawned commands (see "The subprocess Module"). Hint: do not use these tools to launch untrustworthy shell command strings, as they may run any command allowed for the Python process:

`os.system(`*`cmd`*`)`
: Executes a shell command-line string *`cmd`* in a subshell process. Returns the exit status of the spawned process. Unlike `popen()`, does not connect to *`cmd`*'s standard streams via

pipes. Hint: add a `&` at the end of *cmd* to run the command in the background on Unix (e.g., `os.system('python main.py &')`); use a Windows (DOS) `start` command to launch programs easily on Windows (e.g., `os.system('start file.html')`).

`os.startfile(`*`filepathname`*`)`
: Starts a file with its associated application. Acts like double-clicking the file in Windows Explorer or giving the filename as an argument to a Windows `start` command (e.g., with `os.system('start` *`path`*`')`). The file is opened in the application with which its extension is associated; the call does not wait, and does not generally pop up a Windows console window (a.k.a. *Command Prompt*). Windows only, added in version 2.0.

`os.popen(`*`cmd`*`, mode='r', buffering=None)`
: Opens a pipe to or from the shell command-line string *cmd*, to send or capture data. Returns an open file object, which can be used to either read from *cmd*'s standard output stream *stdout* (`mode 'r'`, the default) or write to *cmd*'s standard input stream *stdin* (`mode 'w'`). For example, `dirlist = os.popen('ls –l *.py').read()` reads the output of a Unix `ls` command.

  *cmd* is any command string you can type at your system's console or shell prompt. `mode` can be `'r'` or `'w'` and defaults to `'r'`. `buffering` is the same as in the built-in `open()` function. *cmd* runs independently; its exit status is returned by the resulting file object's `close()` method, except that `None` is returned if exit status is `0` (no errors). Use `readline()` or file object iteration to read output line by line (and possibly interleave operations more fully).

  Python 2.X also has variants `popen2()`, `popen3()`, and `popen4()` to connect to other streams of the spawned command (e.g., `popen2()` returns a tuple (*`child_stdin`*`, `*`child_stdout`*)). In Python 3.X, these calls are removed; use `subprocess.Popen()` instead. The `subprocess` module in version 2.4 and later allows scripts to spawn new processes,

connect to their streams, and obtain their return codes (see "The subprocess Module").

`os.spawn*(args...)`
: A family of functions for spawning programs and commands. See "Process Control" ahead, as well as the Python Library Reference for more details. The `subprocess` module is an alternative to these calls (see "The subprocess Module").

## Environment Tools

These attributes export *execution context*: shell environment, current directory, and so on:

`os.environ`
: The shell environment variable dictionary-like object. `os.environ['USER']` is the value of variable `USER` in the shell (equivalent to `$USER` in Unix and `%USER%` in Windows). Initialized on program start-up. Changes made to `os.environ` by key assignment are exported outside Python using a call to C's `putenv()` and are inherited by any processes that are later spawned in any way, as well as any linked-in C code. See also Python manuals for the `os.environb` environment `bytes` interface in Python 3.2 and later.

`os.putenv(varname, value)`
: Sets the shell environment variable named *varname* to the string *value*. Affects subprocesses started with `system()`, `popen()`, `spawnv()`, `fork()` and `execv()`, and more. Assignment to `os.environ` keys automatically calls `os.putenv()`, but `os.putenv()` calls don't update `os.environ`, so `os.environ` is preferred.

`os.getenv(varname, default=None)`
: Return the value of the environment variable *varname* if it exists, else *default*. At present, this simply indexes the preloaded environment dictionary, with `os.environ.get(varname, default)`. *varname*, *default*, and the result are `str`;

see also Python's manuals for Unicode encoding rules, and `os.getenvb()` for a `bytes` equivalent as of Python 3.2.

`os.getcwd()`
: Returns the current working directory name as a string.

`os.chdir(`*`path`*`)`
: Changes the current working directory for this process to *`path`*, a directory name string. Future file operations are relative to the new current working directory. Hint: this does not update `sys.path` used for module imports, although its first entry may be a generic current working directory designator.

`os.strerror(`*`code`*`)`
: Returns an error message corresponding to *`code`*.

`os.times()`
: Returns a five-tuple containing elapsed CPU time information for the calling process in floating-point seconds: (*`user-time`*, *`system-time`*, *`child-user-time`*, *`child-system-time`*, *`elapsed-real-time`*). Also see "The time Module".

`os.umask(`*`mask`*`)`
: Sets the numeric `umask` to *`mask`* and returns the prior value.

`os.uname()`
: Returns OS name tuple of strings: (*`systemname`*, *`nodename`*, *`release`*, *`version`*, *`machine`*).

## File Descriptor Tools

The following functions process *files by their file descriptors*, where *`fd`* is a file descriptor integer. `os` module file descriptor-based files are meant for low-level file tasks and are not the same as `stdio` file *objects* returned by the built-in `open()` function. File *objects*, not the file *descriptors* here, should normally be used for most file processing. See `open()` in "Built-in Functions" for details. If needed, `os.fdopen()` and the file object's `fileno()` method convert between the two forms, and the built-in `open()` function accepts a file descriptor in 3.X.

**NOTE**

The "*file descriptors*" here are distinct from class "*descriptors*" (see "Methods for Descriptors" for the latter). Also note that Python 3.4 intends to change file descriptors to *not be inherited* by default in subprocesses, and provide new `get_inheritable(fd)` and `set_inheritable(fd, boolean)` calls in `os` to manage this default.

`os.close(fd)`
: Closes file descriptor *fd* (not a file object).

`os.dup(fd)`
: Returns duplicate of file descriptor *fd*.

`os.dup2(fd, fd2)`
: Copies file descriptor *fd* to *fd2* (close *fd2* first if open).

`os.fdopen(fd, *args, **kwargs)`
: Returns a built-in `stdio` file *object* connected to file descriptor *fd* (an integer). This is an alias for the `open()` built-in function and accepts the same arguments, except that first argument of `fdopen()` must always be an integer file descriptor (see `open()` in "Built-in Functions"). A conversion from file descriptor-based files to file objects is normally created automatically by the built-in `open()` function. Hint: use *fileobject*`.fileno()` to convert a file object to a file descriptor.

`os.fstat(fd)`
: Returns status for file descriptor *fd* (like `os.stat()`).

`os.ftruncate(fd, length)`
: Truncates the file corresponding to file descriptor *fd* so that it is at most *length* bytes in size.

`os.isatty(fd)`
: Returns `True` if file descriptor *fd* is open and connected to a tty-like (interactive) device, else `False` (may return `1` or `0` in older Pythons).

`os.lseek(`*`fd, pos, how`*`)`
: Sets the current position of file descriptor *`fd`* to *`pos`* (for random access). `how` can be `0` to set the position relative to the start of the file, `1` to set it relative to the current position, or `2` to set it relative to the end.

`os.open(`*`filename, flags`*`[, mode=0o777], [dir_fd=None])`
: Opens a file descriptor-based file and returns the file descriptor—an integer that may be passed to other `os` module file operation calls, not a `stdio` file object. Intended for low-level file tasks only; not the same as the built-in `open()` function, which is preferred for most file processing (see "Built-in Functions").

  *`filename`* is the file's possibly-relative path name string. *`flags`* is a bitmask: use `|` to combine both platform-neutral and platform-specific flag constants defined in the `os` module (see Table 18). `mode` defaults to `0o777` (octal), and the current `umask` value is first masked out. `dir_fd` is new in Python 3.3, and supports paths relative to directory file descriptors (see Python manuals). Hint: `os.open()` may be used with the `os.O_EXCL` flag to portably lock files for concurrent updates or other process synchronization.

`os.pipe()`
: Create an anonymous pipe. See "Process Control".

`os.read(`*`fd, n`*`)`
: Reads at most *`n`* bytes from file descriptor *`fd`* and returns those bytes as a string.

`os.write(`*`fd, str`*`)`
: Writes all bytes in string *`str`* to file descriptor *`fd`*.

*Table 18. Sample or-able flags for os.open (all os.flag)*

| | | | |
|---|---|---|---|
| O_APPEND | O_EXCL | O_RDONLY | O_TRUNC |
| O_BINARY | O_NDELAY | O_RDWR | O_WRONLY |
| O_CREAT | O_NOCTTY | O_RSYNC | |
| O_DSYNC | O_NONBLOCK | O_SYNC | |

## File Pathname Tools

The following functions *process files* by their pathnames, in which *path* is a string pathname of a file. See also "The os.path Module". In Python 2.X, this module also includes temporary file tools that have been replaced with the `tempfile` module in Python 3.X. As of Python 3.3, some of these tools have grown an additional and optional `dir_fd` argument not shown here, to support paths relative to directory file descriptors; see Python manuals for details:

`os.chdir(`*`path`*`)`

`os.getcwd()`
: Current working directory tools. See "Environment Tools".

`os.chmod(`*`path, mode`*`)`
: Changes mode of file *path* to numeric *mode*.

`os.chown(`*`path, uid, gid`*`)`
: Changes owner/group IDs of *path* to numeric *uid*/*gid*.

`os.link(`*`srcpath, dstpath`*`)`
: Creates a hard link to file *srcpath*, named *dstpath*.

`os.listdir(`*`path`*`)`
: Returns a list of names of all the entries in the directory *path*. A fast and portable alternative to the `glob.glob(`*`pattern`*`)` call and to running shell listing commands with `os.popen()`. See also module `glob` in Python manuals for filename pattern expansion, and `os.walk()` later in this section for full directory tree walking.

  In Python 3.X, this call is passed and returns `bytes` instead of `str` to suppress Unicode filename decoding per platform default (this behavior also applies to `glob.glob()` and `os.walk()`). In Python 3.2 and later, *path* defaults to "." if omitted, the current working directory.

`os.lstat(`*`path`*`)`
: Like `os.stat()`, but does not follow symbolic links.

`os.mkfifo(`*`path`*`[, mode=0o666])`
: Creates a *FIFO* (a named pipe) identified by string *`path`* with access permission given by numeric *`mode`* (but does not open it). The default mode is `0o666` (octal). The current `umask` value is first masked out from the `mode`. This call has a `dir_fd` optional keyword-only argument in 3.3.

  FIFOs are pipes that live in the filesystem and can be opened and processed like regular files, but support synchronized access between independently started clients and servers, by common filename. FIFOs exist until deleted. This call is currently available on Unix-like platforms, including Cygwin on Windows, but not in standard Windows Python. Sockets can often achieve similar goals (see the `socket` module in "Internet Modules and Tools" and Python manuals).

`os.mkdir(`*`path`*`[, `*`mode`*`])`
: Makes a directory called *`path`*, with the given *`mode`*. The default mode is `0o777` (octal).

`os.makedirs(`*`path`*`[, `*`mode`*`])`
: Recursive directory-creation function. Like `mkdir()`, but makes all intermediate-level directories needed to contain the leaf directory. Throws an exception if the leaf directory already exists or cannot be created. `mode` defaults to `0o777` (octal). In Python 3.2 and later, this call has an additional optional argument `exists_ok`; see Python manual.

`os.readlink(`*`path`*`)`
: Returns the path referenced by a symbolic link *`path`*.

`os.remove(`*`path`*`)`

`os.unlink(`*`path`*`)`
: Removes (deletes) the file named *`path`*. `remove()` is identical to `unlink()`. See also `rmdir()` and `removedirs()` in this list for removing directories.

`os.removedirs(`*`path`*`)`
: Recursive directory-removal function. Similar to `rmdir()`, but if the leaf directory is successfully removed, directories

corresponding to the rightmost path segments will then be pruned until either the whole path is consumed or an error is raised. Throws an exception if the leaf directory could not be removed.

`os.rename(`*`srcpath`*`,` *`dstpath`*`)`
: Renames (moves) file *`srcpath`* to name *`dstpath`*. See also `os.replace()` as of Python 3.3 in Python manuals.

`os.renames(`*`oldpath`*`,` *`newpath`*`)`
: Recursive directory- or file-renaming function. Like `rename()`, but creation of any intermediate directories needed to make the new pathname valid is attempted first. After the rename, directories corresponding to the rightmost path segments of the old name will be pruned using `removedirs()`.

`os.rmdir(`*`path`*`)`
: Removes (deletes) a directory named *`path`*.

`os.stat(`*`path`*`)`
: Runs `stat` system call for *`path`*; returns a tuple of integers with low-level file information (whose items are defined and processed by tools in standard library module `stat`).

`os.symlink(`*`srcpath`*`,` *`dstpath`*`)`
: Creates a symbolic link to file *`srcpath`*, called *`dstpath`*.

`os.utime(`*`path`*`, (`*`atime`*`,` *`mtime`*`))`
: Sets file *`path`* access and modification times.

`os.access(`*`path`*`,` *`mode`*`)`
: Consult the Python Library Reference or Unix manpages for details.

```
os.walk(...)
        os.walk(top
          [, topdown=True
          [, onerror=None]
          [, followlinks=False]]])
```

Generates the filenames in a directory tree by walking the tree either top-down or bottom-up. For each directory in the tree rooted at the possibly relative directory path named by string *top* (including *top* itself), yields a three-item tuple (a.k.a. *triple*) (*dirpath*, *dirnames*, *filenames*), where:

- *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 nondirectory files in *dirpath*.

Note that the names in the lists do not contain path components. To get a full path (which begins with *top*) to a file or directory in *dirpath*, run 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 its subdirectories (directories are generated bottom-up). If optional onerror is specified, it should be a function, which will be called with one argument, an os.error instance. By default, os.walk will not walk down into symbolic links that resolve to directories; set followlinks to True to visit directories pointed to by such links, on systems that support them.

When topdown is true, the *dirnames* list may be modified in-place to control the search, as os.walk() will recurse into only the subdirectories whose names remain in *dirnames*. This is useful to prune the search, impose a specific order of visitations, etc.

Python 2.X also provides an os.path.walk() call with similar tree-walking functionality, using an event-handler function callback instead of a generator. In Python 3.X, os.path.walk() is removed due to its redundancy; use os.walk() instead. See also module glob in Python manuals

for related filename expansion (e.g., `glob.glob(r'*\*\*.py')`).

## Process Control

The following functions are used to create and manage *processes and programs*. See also "Shell Commands" for other ways to start programs and files. Hint: do not use these tools to launch untrustworthy shell command strings, as they may run any command allowed for the Python process:

`os.abort()`
: Sends a `SIGABRT` signal to the current process. On Unix, the default behavior is to produce a core dump; on Windows, the process immediately returns exit code 3.

`os.execl(path, arg0, arg1,...)`
: Equivalent to `execv(path, (arg0, arg1,...))`.

`os.execle(path, arg0, arg1,..., env)`
: Equivalent to `execve(path, (arg0, arg1,...), env)`.

`os.execlp(path, arg0, arg1,...)`
: Equivalent to `execvp(path, (arg0, arg1,...))`.

`os.execve(path, args, env)`
: Like `execv()`, but the *env* dictionary replaces the shell variable environment. *env* must map strings to strings.

`os.execvp(path, args)`
: Like `execv(path, args)`, but duplicates the shell's actions in searching for an executable file in a list of directories. The directory list is obtained from `os.environ['PATH']`.

`os.execvpe(path, args, env)`
: A cross between `execve()` and `execvp()`. The directory list is obtained from `os.environ['PATH']`.

`os.execv(path, args)`
: Executes the executable file *path* with the command-line argument *args*, replacing the current program in this process (the Python interpreter). *args* can be a tuple or a list of

strings, and it starts with the executable's name by convention (`argv[0]`). This function call never returns, unless an error occurs while starting the new program.

`os._exit(`*`n`*`)`
: Exits the process immediately with status *n*, without performing normal program termination steps. Normally used only in a child process after a `fork`; the standard way to exit is to call `sys.exit(`*`n`*`)`.

`os.fork()`
: Spawns a child process (a virtual copy of the calling process, running in parallel); returns `0` in the child and the new child's process ID in the parent. Not available in standard Windows Python, but is available on Windows in Cygwin Python (`popen()`, `system()`, `spawnv()`, and the `subprocess` module are generally more portable).

`os.getpid()`

`os.getppid()`
: Returns the process ID of the current (calling) process; `getppid()` returns the parent process ID.

`os.getuid()`

`os.geteuid()`
: Returns the process's user ID; `geteuid` returns the effective user ID.

`os.kill(`*`pid, sig`*`)`
: Send signal *`sig`* to the process with ID *`pid`*, potentially killing it (for some signal types). See also the `signal` standard library module in Python manuals for signal constants and signal handler registration.

`os.mkfifo(`*`path`*`[, `*`mode`*`])`
: See the earlier section "File Pathname Tools" (named files used for process synchronization).

`os.nice(`*`increment`*`)`
: Adds *`increment`* to process's "niceness" (i.e., lowers its CPU priority).

`os.pipe()`
: Returns a tuple of file descriptors (*`readfd, writefd`*) for reading and writing a new anonymous (unnamed) pipe. Used for cross-process communication of related processes.

`os.plock(`*`op`*`)`
: Locks program segments into memory. *`op`* (defined in `<sys./lock.h>`) determines which segments are locked.

`os.spawnv(`*`mode, path, args`*`)`
: Executes program *`path`* in a new process, passing the arguments specified in *`args`* as a command line. *`args`* can be a list or a tuple. *`mode`* is an operational constant made from the following names, also defined in the `os` module: `P_WAIT`, `P_NOWAIT`, `P_NOWAITO`, `P_OVERLAY`, and `P_DETACH`. On Windows, roughly equivalent to a `fork()` plus `execv()` combination. (`fork()` is not available on standard Windows Python, although `popen()` and `system()` are.) See also the standard library `subprocess` module for more feature-rich alternatives to this call (see "The subprocess Module").

`os.spawnve(`*`mode, path, args, env`*`)`
: Like `spawnv()`, but passes the contents of mapping *`env`* as the spawned program's shell environment (else it would inherit its parent's).

`os.wait()`
: Waits for completion of a child process. Returns a tuple with child's ID and exit status.

`os.waitpid(`*`pid, options`*`)`
: Waits for child process with ID *`pid`* to complete. *`options`* is `0` for normal use, or `os.WNOHANG` to avoid hanging if no child status is available. If *`pid`* is `0`, the request applies to any child in the process group of the current process. See also the process exit status-check functions documented in the Python Library Reference (e.g., `WEXITSTATUS(`*`status`*`)` to extract the exit code).

## The os.path Module

The `os.path` module provides additional file *directory pathname-related* services and portability tools. This is a nested module: its names are nested in the `os` module within the submodule `os.path` (e.g., the `exists` function may be obtained by importing `os` and using name `os.path.exists`).

Most functions in this module take an argument *`path`*, the string directory pathname of a file (e.g., `'C:\dir1\spam.txt'`). Directory paths are generally coded per the platform's conventions and are mapped to the current working directory if lacking a directory prefix. Hint: forward slashes usually work as directory separators on all platforms. In Python 2.X, this module includes an `os.path.walk()` tool, which has been replaced by `os.walk()` in Python 3.X (see "File Pathname Tools"):

`os.path.abspath(`*`path`*`)`
: Returns a normalized absolute version of *`path`*. On most platforms, this is equivalent to `normpath(join(os.getcwd(),` *`path`*`))`.

`os.path.basename(`*`path`*`)`
: Same as second half of pair returned by `split(`*`path`*`)`.

`os.path.commonprefix(`*`list`*`)`
: Returns longest path prefix (character by character) that is a prefix of all paths in *`list`*.

`os.path.dirname(`*`path`*`)`
: Same as first half of pair returned by `split(`*`path`*`)`.

`os.path.exists(`*`path`*`)`
: True if string *`path`* is the name of an existing file path.

`os.path.expanduser(`*`path`*`)`
: Returns string that is *`path`* with embedded `~` username expansion done.

`os.path.expandvars(`*`path`*`)`
: Returns string that is *`path`* with embedded `$` environment variables expanded.

`os.path.getatime(`*`path`*`)`
: Returns time of last access of *`path`* (seconds since the epoch).

`os.path.getmtime(`*`path`*`)`
: Returns time of last modification of *`path`* (seconds since the epoch).

`os.path.getsize(`*`path`*`)`
: Returns size, in bytes, of file *`path`*.

`os.path.isabs(`*`path`*`)`
: True if string *`path`* is an absolute path.

`os.path.isfile(`*`path`*`)`
: True if string *`path`* is a regular file.

`os.path.isdir(`*`path`*`)`
: True if string *`path`* is a directory.

`os.path.islink(`*`path`*`)`
: True if string *`path`* is a symbolic link.

`os.path.ismount(`*`path`*`)`
: True if string *`path`* is a mount point.

`os.path.join(`*`path1`*`[, `*`path2`*`[, ...]])`
: Joins one or more path components intelligently (using platform-specific separator conventions between each part).

`os.path.normcase(`*`path`*`)`
: Normalizes case of a pathname. Has no effect on Unix; on case-insensitive filesystems, converts to lowercase; on Windows, also converts `/` to `\`.

`os.path.normpath(`*`path`*`)`
: Normalizes a pathname. Collapses redundant separators and up-level references; on Windows, converts `/` to `\`.

`os.path.realpath(`*`path`*`)`
: Returns the canonical path of the specified filename, eliminating any symbolic links encountered in the path.

`os.path.samefile(path1, path2)`
: True if both pathname arguments refer to the same file or directory.

`os.path.sameopenfile(fp1, fp2)`
: True if both file objects refer to the same file.

`os.path.samestat(stat1, stat2)`
: True if both `stat` tuples refer to the same file.

`os.path.split(path)`
: Splits *`path`* into (*`head, tail`*), where *`tail`* is the last pathname component and *`head`* is everything leading up to *`tail`*. Same as tuple (`dirname(`*`path`*`), basename(`*`path`*`)`).

`os.path.splitdrive(path)`
: Splits *`path`* into a pair (`'`*`drive`*`:', `*`tail`*) (on Windows).

`os.path.splitext(path)`
: Splits *`path`* into (*`root, ext`*), where the last component of *`root`* contains no `.`, and *`ext`* is empty or starts with a `.`.

`os.path.walk(path, visitor, data)`
: An alternative to `os.walk()` in Python 2.X only, and based on directory-handler callback function *`visitor`* with state *`data`*, instead of directory generator. Removed in Python 3.X: use `os.walk()`, not `os.path.walk()`.

# The re Pattern-Matching Module

The `re` module is the standard regular expression *pattern-matching* interface in both Python 3.X and 2.X. Regular expression (RE) patterns, and the text to be matched by them, are specified as strings. This module must be imported.

## Module Functions

The module's top-level interface includes tools to match immediately or precompile patterns, and creates pattern objects (*`pobj`*) and match objects (*`mobj`*) defined in subsequent sections:

`re.compile(`*`pattern`*`[, `*`flags`*`])`

Compile an RE *`pattern`* string into a RE pattern object (*`pobj`*), for later matching. *`flags`* (combinable by bitwise `|` operator) include the following, available at the top-level of the `re` module:

`re.A` *or* `re.ASCII` *or* `(?a)`

Makes `\w`, `\W`, `\b`, `\B`, `\s`, and `\S` perform ASCII-only matching instead of full Unicode matching. This is meaningful only for Unicode patterns and is ignored for byte patterns. Note that for backward compatibility, the `re.U` flag still exists (as well as its synonym `re.UNICODE` and its embedded counterpart, `?u`), but these are redundant in Python 3.X since matches are Unicode by default for strings (and Unicode matching isn't allowed for bytes).

`re.I` *or* `re.IGNORECASE` *or* `(?i)`

Case-insensitive matching.

`re.L` *or* `re.LOCALE` *or* `(?L)`

Makes `\w`, `\W`, `\b`, `\B`, `\s`, `\S`, `\d`, and `\D` dependent on the current locale (default is Unicode for Python 3.X).

`re.M` *or* `re.MULTILINE` *or* `(?m)`

Matches to each newline, not whole string.

`re.S` *or* `re.DOTALL` *or* `(?s)`

`.` matches *all* characters, including newline.

`re.U` *or* `re.UNICODE` *or* `(?u)`

Makes `\w`, `\W`, `\b`, `\B`, `\s`, `\S`, `\d`, and `\D` dependent on Unicode character properties (new in version 2.0, and superfluous in Python 3.X).

`re.X` *or* `re.VERBOSE` *or* `(?x)`

Ignores whitespace in the pattern, outside character sets.

`re.match(`*`pattern`*`, `*`string`*`[, `*`flags`*`])`
: If zero or more characters at start of *`string`* match the *`pattern`* string, returns a corresponding match object instance (*`mobj`*), or `None` if no match. *`flags`* is as in `compile()`.

`re.search(`*`pattern`*`, `*`string`*`[, `*`flags`*`])`
: Scans through *`string`* for a location matching *`pattern`*; returns a corresponding match object instance (*`mobj`*), or `None` if no match. *`flags`* is as in `compile()`.

`re.split(`*`pattern`*`, `*`string`*`[, maxsplit=0])`
: Splits *`string`* by occurrences of *`pattern`*. If capturing `()` are used in *`pattern`*, occurrences of patterns or subpatterns are also returned.

`re.sub(`*`pattern`*`, `*`repl`*`, `*`string`*`[, count=0])`
: Returns string obtained by replacing the (first count) leftmost nonoverlapping occurrences of *`pattern`* (a string or an RE object) in *`string`* by *`repl`*. *`repl`* can be a string or a function called with a single match object (*`mobj`*) argument, which must return the replacement string. *`repl`* can also include sequence escapes `\1`, `\2`, etc., to use substrings that match groups, or `\0` for all.

`re.subn(`*`pattern`*`, `*`repl`*`, `*`string`*`[, count=0])`
: Same as *`sub`* but returns a tuple (*`new-string`*`, `*`number-of-subs-made`*).

`re.findall(`*`pattern`*`, `*`string`*`[, `*`flags`*`])`
: Returns a list of strings giving all nonoverlapping matches of *`pattern`* in *`string`*. If one or more groups are present in the pattern, returns a list of groups.

`re.finditer(`*`pattern`*`, `*`string`*`[, `*`flags`*`])`
: Returns an iterable over all nonoverlapping matches for the RE pattern in string (match objects).

`re.escape(`*`string`*`)`
: Returns *`string`* with all nonalphanumeric characters backslashed, such that they can be compiled as a string literal.

## Regular Expression Objects

RE pattern objects (*pobj*) are returned by the `re.compile()` and have the following attributes, some of which create match objects (*mobj*):

*pobj*`.flags`
: The `flags` argument used when the RE patterns object was compiled.

*pobj*`.groupindex`
: Dictionary of {*group-name*: *group-number*} in the pattern.

*pobj*`.pattern`
: The pattern string from which the RE pattern object was compiled.

*pobj*`.match(`*string*`[, `*pos*`[, `*endpos*`]])`
*pobj*`.search(`*string*`[, `*pos*`[, `*endpos*`]])`
*pobj*`.split(`*string*`[, maxsplit=0])`
*pobj*`.sub(`*repl*`, `*string*`[, count=0])`
*pobj*`.subn(`*repl*`, `*string*`[, count=0])`
*pobj*`.findall(`*string*`[, `*pos*`[, `*endpos*`]])`
*pobj*`.finditer(`*string*`[, `*pos*`[, `*endpos*`]])`
: Same as earlier `re` module functions, but *pattern* is implied, and *pos* and *endpos* give start/end string indexes for the match. The first two may create match objects (*mobj*).

## Match Objects

Match objects (*mobj*) are returned by successful `match()` and `search()` operations, and have the following attributes (see the Python Library Reference for additional lesser-used attributes omitted here):

*mobj*`.pos`, *mobj*`.endpos`
: Values of `pos` and `endpos` passed to `search` or `match`.

*mobj*`.re`
: RE pattern object whose `match` or `search` produced this match object (see its `pattern` string).

*mobj*.string
: String passed to match or search.

*mobj*.group([*g* [, *g*]*)
: Returns substrings that were matched by parenthesized groups in the pattern. Accepts zero or more group *number* or *name* identifiers *g*, implied by patterns (R) and (?P<*name*>*R*), respectively. If one argument, result is the substring that matched the group whose identifier passed. If multiple arguments, result is a tuple with one matched substring per argument. If no arguments, returns entire matching substring. If any group number is 0, return value is entire matching string; otherwise, returns string matching corresponding parenthesized group. Groups in pattern are numbered 1...N, from left to right.

*mobj*.groups()
: Returns a tuple of all groups of the match; groups not participating in the match have a value of None.

*mobj*.groupdict()
: Returns a dictionary containing all the named subgroups of the match, keyed by the subgroup name.

*mobj*.start([*g*]), *mobj*.end([*g*])
: Indexes of start and end of substring matched by group *g* (or entire matched string, if no *group*). For a match object *M*, *M*.string[*M*.start(*g*):*M*.end(*g*)] == *M*.group(*g*).

*mobj*.span([*g*])
: Returns the tuple (*mobj*.start(*g*), *mobj*.end(*g*)).

*mobj*.expand(*template*)
: Returns the string obtained by doing backslash substitution on the string *template*, as done by the sub method. Escapes such as \n are converted to the appropriate characters, and numeric back-references (e.g., \1, \2) and named back-references (e.g., \g<1>, \g<name>) are replaced by the corresponding group.

## Pattern Syntax

Pattern strings are specified by concatenating forms (see Table 19), as well as by character class escapes (see Table 20). Python character escapes (e.g., `\t` for tab) can also appear. Pattern strings are matched against text strings, yielding a Boolean match result, as well as grouped substrings matched by subpatterns in parentheses:

```
>>> import re
>>> pobj = re.compile('hello[ \t]*(.*)')
>>> mobj = pobj.match('hello  world!')
>>> mobj.group(1)
'world!'
```

In Table 19, *C* is any character, *R* is any regular expression form in the left column of the table, and *m* and *n* are integers. Each form usually consumes as much of the string being matched as possible, except for the nongreedy forms (which consume as little as possible, as long as the entire pattern still matches the target string).

*Table 19. Regular expression pattern syntax*

| Form | Description |
|---|---|
| `.` | Matches any character (including newline if `DOTALL` flag is specified). |
| `^` | Matches start of string (of every line in `MULTILINE` mode). |
| `$` | Matches end of string (of every line in `MULTILINE` mode). |
| *C* | Any nonspecial character matches itself. |
| *R*`*` | Zero or more occurrences of preceding regular expression *R* (as many as possible). |
| *R*`+` | One or more occurrences of preceding regular expression *R* (as many as possible). |
| *R*`?` | Zero or one occurrence of preceding regular expression *R*. |
| *R*`{`*m*`}` | Matches exactly *m* repetitions of preceding regular expression *R*. |

| Form | Description |
|---|---|
| *R*{*m*,*n*} | Matches from *m* to *n* repetitions of preceding regular expression *R*. |
| *R**?, *R*+?, *R*??, *R*{*m*,*n*}? | Same as *, +, and ?, but matches as few characters/times as possible; *nongreedy*. |
| [...] | Defines character set; e.g., [a-zA-Z] matches all letters (also see Table 20). |
| [^...] | Defines complemented character set: matches if character is not in set. |
| \ | Escapes special characters (e.g., *?+\|()) and introduces special sequences (see Table 20). Due to Python rules, write as \\ or r'\\'. |
| \\ | Matches a literal \; due to Python string rules, write as \\ \\ in pattern, or r'\\'. |
| *number* | Matches the contents of the group of the same number: r'(.+) \1' matches '42 42'. |
| *R*\|*R* | Alternative: matches left or right *R*. |
| *RR* | Concatenation: matches both *R*s. |
| (*R*) | Matches any RE inside (), and delimits a *group* (retains matched substring). |
| (?:*R*) | Same as (*R*) but doesn't delimit a group. |
| (?=*R*) | Look-ahead assertion: matches if *R* matches next, but doesn't consume any of the string (e.g., 'X(?=Y)' matches X if followed by Y). |
| (?!*R*) | Negative look-ahead assertion: matches if *R* doesn't match next. Negative of (?=*R*). |
| (?P<*name*>*R*) | Matches any RE inside () and delimits a named group (e.g., r'(?P<id>[a-zA-Z_]\w*)' defines a group named id). |
| (?P=*name*) | Matches whatever text was matched by the earlier group named *name*. |
| (?#...) | A comment; ignored. |

| Form | Description |
|---|---|
| (?*letter*) | *letter* is one of a, i, L, m, s, x, or u. Set flag (re.A, re.I, re.L, etc.) for entire RE. |
| (?<=*R*) | Positive look-behind assertion: matches if preceded by a match of fixed-width *R*. |
| (?<!*R*) | Negative look-behind assertion: matches if not preceded by a match of fixed-width *R*. |
| (?(*id/name*)*yespatt*\|*nopatt*) | Will try to match with pattern *yespatt* if the group with given *id* or *name* exists, else with optional *nopatt*. |

In Table 20, \b, \B, \d, \D, \s, \S, \w, and \W behave differently depending on flags, and defaults to Unicode in Python 3.X, unless ASCII (a.k.a. ?a) is used. Tip: use raw strings (r'\n') to literalize backslashes in Table 20 class escapes.

*Table 20. Regular expression pattern special sequences*

| Sequence | Description |
|---|---|
| *number* | Matches text of the group *number* (from 1) |
| \A | Matches only at the start of the string |
| \b | Empty string at word boundaries |
| \B | Empty string not at word boundary |
| \d | Any decimal digit (like [0-9]) |
| \D | Any nondecimal digit character (like [^0-9]) |
| \s | Any whitespace character (like [ \t\n\r\f\v]) |
| \S | Any nonwhitespace character (like [^ \t\n\r\f\v]) |
| \w | Any alphanumeric character |
| \W | Any nonalphanumeric character |
| \Z | Matches only at the end of the string |

# Object Persistence Modules

Three modules comprise the standard library's *object persistence* (Python object storage) system:

`dbm` (`anydbm` in Python 2.X)
: Key-based string-only storage files.

`pickle` (and `cPickle` in Python 2.X)
: Serializes an in-memory object to/from file streams.

`shelve`
: Key-based persistent object stores: stores objects in `dbm` files in `pickle` form.

The `shelve` module implements persistent object stores. `shelve` in turn uses the `pickle` module to convert (serialize) in-memory Python objects to linear strings and the `dbm` module to store those linear strings in access-by-key files. All three modules can be used directly.

---

**NOTE**

In Python 2.X, `dbm` is named `anydbm`, and the `cPickle` module is an optimized version of `pickle` that may be imported directly and is used automatically by `shelve`, if present. In Python 3.X, `cPickle` is renamed `_pickle` and is automatically used by `pickle` if present—it need not be imported directly and is acquired by `shelve`.

Also note that in Python 3.X the Berkeley DB (a.k.a. `bsddb`) interface for `dbm` is no longer shipped with Python itself, but is a third-party open source extension, which must be installed separately if needed (see the Python 3.X Library Reference for resources).

---

## The shelve and dbm Modules

`dbm` is a simple *access-by-key text file*: strings are stored and fetched by their string keys. The `dbm` module selects the keyed-access file implementation available in your Python interpreter and presents a dictionary-like API for scripts.

`shelve` is an *access-by-key object file*: it is used like a simple *dbm* file, except that module name differs, and the stored *value* can be almost any kind of Python object (although *keys* are still strings). In most respects, dbm files and shelves work like *dictionaries* that must be opened before use, and closed after making changes; all mapping operations and some dictionary methods work, and are automatically mapped to external files.

### File opens

For `shelve`, import the library, and call its `open()` to create a new or open an existing shelve file:

```
import shelve
file = shelve.open(filename
          [, flag='c'
          [, protocol=None
          [, writeback=False]]])
```

For `dbm`, import the library, and call its `open()` to create a new or open an existing dbm file. This employs whatever `dbm` support library is available: `dbm.bsd`, `dbm.gnu`, `dbm.ndbm`, or `dbm.dumb` (the last being a fallback default always present):

```
import dbm
file = dbm.open(filename
          [, flag='r'
          [, mode]])
```

*`filename`* in both `shelve` and `dbm` is a relative or absolute string name of an external file where data is stored.

`flag` is the same in `shelve` and `dbm` (`shelve` passes it on to `dbm`). It can be `'r'` to open an existing database for reading only (`dbm` default); `'w'` to open an existing database for reading and writing;

'c' to create the database if it doesn't exist (shelve default); or 'n', which will always create a new empty database. The dbm.dumb module (used by default in 3.X if no other library is installed) ignores flag—the database is always opened for update and is created if it doesn't exist.

For dbm, the optional mode argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666.

For shelve, the protocol argument is passed on from shelve to pickle. It gives the pickling protocol number (described in "The pickle Module") used to store shelved objects; it defaults to 0 in Python 2.X, and currently to 3 in Python 3.X.

By default, changes to objects fetched from shelves are not automatically written back to disk. If the optional writeback parameter is set to True, all entries accessed are cached in memory, and written back at close time; this makes it easier to mutate mutable entries in the shelve, but can consume memory for the cache, making the close operation slow because all accessed entries are written back. Reassign objects to their keys to update shelves manually.

### File operations

Once created, shelve and dbm have nearly identical, dictionary-like interfaces, as follows:

```
file[key] = value
```

Store: creates or changes the entry for string *key*. The *value* is a string for dbm, or a nearly arbitrary object for shelve.

```
value = file[key]
```

Fetch: loads the *value* for the *key* entry. For shelve, reconstructs the original object in memory.

```
count = len(file)
```

Size: returns the number of entries stored.

```
index = file.keys()
```

Index: fetches the stored keys iterable (a list in 2.X).

```
for key in file: ...
```

Iterate: keys iterator, usable in any iteration context.

```
found = key in file    # Also has_key() in 2.X only
```

Query: `True` if there's an entry for *key*.

```
del file[key]
```

Delete: removes the entry for *key*.

```
file.close()
```

Manual close; required to flush updates to disk for some underlying `dbm` interfaces.

## The pickle Module

The `pickle` module is an *object serialization* tool: it converts nearly arbitrary in-memory Python objects to/from linear byte-streams. These byte-streams can be directed to any file-like object that has the expected read/write methods, and are used by `shelve` as its internal data representation. Unpickling re-creates the original in-memory object, with the same value, but a new identity (memory address).

See the earlier note about Python 2.X's `cPickle` and Python 3.X's `_pickle` optimized modules. Also see the `makefile` method of `socket` objects for shipping serialized objects over networks without manual socket calls (see "Internet Modules and Tools" and Python manuals).

### Pickling interfaces

This module supports the following calls:

```
P = pickle.Pickler(fileobject [, protocol=None])
```

Makes a new pickler, for saving to an output file object.

```
P.dump(object)
```

Writes an object onto the pickler's file/stream.

```
pickle.dump(object, fileobject [, protocol=None])
```

Combination of the previous two: pickles object onto file.

```
string = pickle.dumps(object [, protocol=None])
```

Returns pickled representation of object as a string (a `bytes` string in Python 3.X).

### Unpickling interfaces

This module supports the following calls:

```
U = pickle.Unpickler(fileobject,
                     encoding="ASCII", errors="strict")
```

Makes unpickler, for loading from input file object.

```
object = U.load()
```

Reads object from the unpickler's file/stream.

```
object = pickle.load(fileobject,
                     encoding="ASCII", errors="strict")
```

Combination of the previous two: unpickles object from file.

```
object = pickle.loads(string,
                      encoding="ASCII", errors="strict")
```

Reads object from a string (a `bytes` or compatible string in Python 3.X).

### pickle usage notes

- In Python 3.X, files used to store pickled objects should always be opened in binary mode for all protocols, because the pickler produces `bytes` strings, and text mode files do not support writing `bytes` (text mode files encode and decode Unicode text in 3.X).

- In Python 2.X, files used to store pickled objects must be opened in binary mode for all pickle protocols >= `1`, to suppress line-end translations in binary pickled data. Protocol `0` is ASCII-based, so its files may be opened in either text or binary mode, as long as this is done consistently.
- *`fileobject`* is an open file object, or any object that implements file object attributes called by the interface. `Pickler` calls the file `write()` method with a string argument. `Unpickler` calls the file `read()` method with a byte-count and `readline()` without arguments.
- `protocol` is an optional argument that selects a format for pickled data, available in both the `Pickler` constructor and the module's `dump()` and `dumps()` convenience functions. This argument takes a value `0`...`3`, where higher protocol numbers are generally more efficient, but may also be incompatible with unpicklers in earlier Python releases. The default protocol number in Python 3.X is `3`, which cannot be unpickled by Python 2.X. The default protocol in Python 2.X is `0`, which is less efficient but most portable. Protocol `-1` automatically uses the highest protocol supported. When *unpickling*, protocol is implied by pickled data contents.
- The unpickler's `encoding` and `errors` optional keyword-only arguments are available in Python 3.X only. They are used to decode 8-bit string instances pickled by Python 2.X. These default to `'ASCII'` and `'strict'`, respectively. See `str()` in "Built-in Functions" for similar tools.
- `Pickler` and `Unpickler` are exported classes that may be customized by subclassing. See the Python Library Reference for available methods.

**NOTE**

At this writing, there is a proposal (PEP) for an optimized pickle `protocol` number 4. It targets Python 3.4, but is still draft status, so it's unclear if and when it will appear. If it does, it may be the new 3.X default, and may be backward-incompatible with and unrecognized by all earlier Pythons. *Late breaking update:* this change is now official in 3.4, per its first beta release; see Python "What's New" documents for details.

# The tkinter GUI Module and Tools

`tkinter` (named `Tkinter` in Python 2.X, and a module package in Python 3.X) is a portable *graphical user interface* (GUI) construction library shipped with Python as a standard library module. `tkinter` provides an object-based interface to the open source Tk library and implements native look and feel for Python-coded GUIs on Windows, X-Windows, and Mac OS. It is portable, simple to use, well documented, widely used, mature, and well supported. Other portable GUI options for Python, such as *wxPython* and *PyQT*, are third-party extensions with richer widget sets but generally more complex coding requirements.

## tkinter Example

In `tkinter` scripts, *widgets* are customizable classes (e.g., `Button`, `Frame`), *options* are keyword arguments (e.g., `text="press"`), and *composition* refers to object embedding, not pathnames (e.g., `Label(top,...)`):

```
from tkinter import *           # Widgets, constants

def msg():                      # Callback handler
    print('hello stdout...')

top = Frame()                   # Make a container
top.pack()
Label(top, text='Hello world').pack(side=TOP)
```

```
widget = Button(top, text='press', command=msg)
widget.pack(side=BOTTOM)
top.mainloop()
```

## tkinter Core Widgets

Table 21 lists the primary widget classes in the `tkinter` module. These are Python classes that can be subclassed and embedded in other objects. To create a screen device, make an instance of the corresponding class, configure it, and arrange it with one of the geometry manager interface methods (e.g., `Button(text='hello').pack()`). In addition to Table 21's classes, the `tkinter` module provides a large set of predefined names (a.k.a. constants) used to configure widgets (e.g., `RIGHT`, `BOTH`, `YES`); these are automatically loaded from `tkinter.constants` (`Tkconstants` in Python 2.X).

*Table 21. Module tkinter core widget classes*

| Widget class | Description |
|---|---|
| `Label` | Simple message area |
| `Button` | Simple labeled pushbutton widget |
| `Frame` | Container for attaching and arranging other widget objects |
| `Toplevel, Tk` | Top-level windows managed by the window manager |
| `Message` | Multiline text-display field (label) |
| `Entry` | Simple single-line text entry field |
| `Checkbutton` | Two-state button widget, used for multiple-choice selections |
| `Radiobutton` | Two-state button widget, used for single-choice selections |
| `Scale` | A slider widget with scalable positions |
| `PhotoImage` | Image object for placing full-color images on other widgets |
| `BitmapImage` | Image object for placing bitmap images on other widgets |
| `Menu` | Options associated with a `Menubutton` or top-level window |
| `Menubutton` | Button that opens a `Menu` of selectable options/submenus |
| `Scrollbar` | Bar for scrolling other widgets (e.g., `Listbox`, `Canvas`, `Text`) |

| Widget class | Description |
|---|---|
| `Listbox` | List of selection names |
| `Text` | Multiline text browse/edit widget, support for fonts, etc. |
| `Canvas` | Graphics drawing area: lines, circles, photos, text, etc. |
| `OptionMenu` | *Composite*: pull-down selection list |
| `PanedWindow` | A multipane window interface |
| `LabelFrame` | A labeled frame widget |
| `Spinbox` | A multiple selection widget |
| `ScrolledText` | Python 2.X name (available in module `tkinter.scrolledtext` in Python 3.X); *Composite*: text with attached scrollbar |
| `Dialog` | Python 2.X name (available in module `tkinter.dialog` in Python 3.X); *Old*: common dialog maker (see newer common dialog calls in the next section) |

# Common Dialog Calls

## Module tkinter.messagebox (tkMessageBox in Python 2.X)

```
showinfo(title=None, message=None, **options)
showwarning(title=None, message=None, **options)
showerror(title=None, message=None, **options)
askquestion(title=None, message=None, **options)
askokcancel(title=None, message=None, **options)
askyesno(title=None, message=None, **options)
askretrycancel(title=None, message=None, **options)
```

## Module tkinter.simpledialog (tkSimpleDialog in Python 2.X)

```
askinteger(title, prompt, **kw)
askfloat(title, prompt, **kw)
askstring(title, prompt, **kw)
```

## Module tkinter.colorchooser (tkColorChooser in Python 2.X)

```
askcolor(color=None, **options)
```

### Module tkinter.filedialog (tkFileDialog in Python 2.X)

```
class Open
class SaveAs
class Directory
askopenfilename(**options)
asksaveasfilename(**options)
askopenfile(mode="r", **options)
asksaveasfile(mode="w", **options)
askdirectory(**options)
```

The common dialog call *options* are `defaultextension` (added to filename if not explicitly given), `filetypes` (sequence of `(label, pattern)` tuples), `initialdir` (initial directory, remembered by classes), `initialfile` (initial file), `parent` (window in which to place the dialog box), and `title` (dialog box title).

## Additional tkinter Classes and Tools

Table 22 lists some commonly used tkinter interfaces and tools beyond the core widget class and standard dialog set. All of these are standard library tools, except some in the last row (e.g., Pillow); see the Web.

*Table 22. Additional tkinter tools*

| Tool category | Available tools |
|---|---|
| tkinter linked-variable classes | `StringVar`, `IntVar`, `DoubleVar`, `BooleanVar` (in `tkinter` module) |
| Geometry management methods | `pack()`, `grid()`, `place()` widget object methods, plus configuration options in module |
| Scheduled callbacks | Widget `after()`, `wait()`, and `update()` methods; file I/O callbacks |
| Other tkinter tools | Clipboard access; `bind()`/`Event` low-level event processing widget object methods; widget `config()` options; modal dialog box support |
| tkinter extensions | *PMW*: more widgets; *PIL* (a.k.a *Pillow*): images; tree widgets, font support, drag-and-drop, tix widgets, ttk themed widgets, etc. |

## Tcl/Tk-to-Python/tkinter Mappings

Table 23 compares Python's `tkinter` API to the base Tk library as exposed by the Tcl language, Tk's now-distant origin. In general, Tcl's command strings map to objects in the Python language. Specifically, in Python's `tkinter`, the Tk GUI interface differs from Tcl in the following ways:

*Creation*
: Widgets are created as class instance objects by calling a widget class.

*Masters (parents)*
: Parents are previously created objects, passed to widget class constructors.

*Widget options*
: Options are constructor or `config()` keyword arguments, or indexed keys.

*Operations*
: Widget operations (actions) become `tkinter` widget class object methods.

*Callbacks*
: Callback handlers are any callable object: function, method, `lambda`, class with `__call__` method, etc.

*Extension*
: Widgets are extended using Python class inheritance mechanisms.

*Composition*
: Interfaces are constructed by attaching objects, not by concatenating names.

*Linked variables*
: Variables associated with widgets are `tkinter` class objects with methods.

*Table 23. Tk-to-tkinter mappings*

| Operation | Tcl/Tk | Python/tkinter |
|---|---|---|
| Creation | `frame .panel` | `panel = Frame()` |
| Masters | `button .panel.quit` | `quit = Button(panel)` |
| Options | `button .panel.go -fg black` | `go = Button(panel, fg='black')` |
| Configure | `.panel.go config -bg red` | `go.config(bg='red')`<br>`go['bg'] = 'red'` |
| Actions | `.popup invoke` | `popup.invoke()` |
| Packing | `pack .panel -side left -fill x` | `panel.pack(side=LEFT, fill=X)` |

# Internet Modules and Tools

This section summarizes Python's support for *Internet scripting* in Python 3.X and 2.X. It gives brief overviews of some of the more commonly used modules in the Python standard library's Internet modules set. *This is just a representative sample*; see the Python Library Reference for a more complete list:

`socket`
: Low-level network communications support (TCP/IP, UDP, etc.). Interfaces for sending and receiving data over BSD-style sockets: `socket.socket()` makes an object with socket call methods (e.g., *`object`*`.bind()`). Most protocol and server modules use this module internally.

`socketserver` (`SocketServer` in Python 2.X)
: Framework for general threading and forking network servers.

`xdrlib`
: Encodes binary data portably (also see `socket` modules earlier in this list).

`select`
: Interfaces to Unix and Windows `select()` function. Waits for activity on one of a set of files or sockets. Commonly used to multiplex among multiple streams or to implement time-outs. Works only for sockets on Windows, not files.

`cgi`
: Server-side CGI script support: `cgi.FieldStorage()` parses the input stream; `cgi.escape()` (and `html.escape()` in recent 3.X) applies HTML escape conventions to output streams. To parse and access form information: after a CGI script calls *`form`*`=cgi.FieldStorage()`, *`form`* is a dictionary-like object with one entry per form field (e.g., *`form`*`["name"].value` is form's `name` field text).

`urllib.request` (`urllib`, `urllib2` in Python 2.X)
: Fetches web pages and server script outputs from their Internet addresses (URLs): `urllib.request.urlopen(`*`url`*`)` returns a file-like object with `read` methods; also `urllib.request.urlretrieve(`*`remote`*`, `*`local`*`)`. Supports HTTP, HTTPS, FTP, and local file URLs.

`urllib.parse` (`urlparse` in Python 2.X)
: Parses URL string into components. Also contains tools for escaping URL text: `urllib.parse.quote_plus(`*`str`*`)` does URL escapes for text inserted into HTML output streams.

`ftplib`
: FTP (file transfer protocol) modules. `ftplib` provides interfaces for Internet file transfers in Python programs. After *`ftp`*`=ftplib.FTP('`*`sitename`*`')`, *`ftp`* has methods for login, changing directories, fetching/storing files and listings, etc. Supports binary and text transfers; works on any machine with Python and a usable Internet connection.

`poplib`, `imaplib`, `smtplib`
: POP, IMAP (mail fetch), and SMTP (mail send) protocol modules.

`email` package
: Parses and constructs email messages with headers and attachments. Also contains MIME support for both content and headers.

`http.client` (`httplib` in Python 2.X), `nntplib`, `telnetlib`
: HTTP (web), NNTP (news), and Telnet protocol client modules.

`http.server` (`CGIHTTPServer`, `SimpleHTTPServer` in Python 2.X)
: HTTP request server implementations.

`xml` package, `html` package (`htmllib` in Python 2.X)
: Parse XML and HTML documents and web page contents. `xml` package supports DOM, SAX, and ElementTree parsing models, with Expat parsing.

`xmlrpc` package (`xmlrpclib` in Python 2.X)
: XML-RPC remote method call protocol.

`uu`, `binhex`, `base64`, `binascii`, `quopri`
: Encodes and decodes binary (or other) data transmitted as text.

Table 24 lists some of these modules by protocol type; see the preceding list for 2.X names that differ.

*Table 24. Selected Python 3.X Internet modules by protocol*

| Protocol | Common function | Port number | Python module |
|---|---|---|---|
| HTTP | Web pages | 80 | `http.client`, `urllib.request`, `xmlrpc.*` |
| NNTP | Usenet news | 119 | `nntplib` |
| FTP data default | File transfers | 20 | `ftplib`, `urllib.request` |
| FTP control | File transfers | 21 | `ftplib`, `urllib.request` |
| SMTP | Sending email | 25 | `smtplib` |

| Protocol | Common function | Port number | Python module |
|---|---|---|---|
| POP3 | Fetching email | 110 | `poplib` |
| IMAP4 | Fetching email | 143 | `imaplib` |
| Telnet | Command lines | 23 | `telnetlib` |

# Other Standard Library Modules

This section documents a handful of additional standard library modules installed with Python itself. Unless otherwise noted, tools covered here apply to both Python 3.X and 2.X. See the Python Library Reference for details on all built-in tools, and the PyPI website (described in "Assorted Hints") or your favorite web search engine for third-party modules and tools.

## The math Module

The `math` module exports C standard *math library tools* for use in Python. Table 25 lists this module's exports in Python 3.3, with seven recent additions in 3.2 and 3.3 in bold font. Python 2.7's module is identical, but has no `log2` or `isfinite`. Contents of this table may vary slightly in other releases. All its entries are callable functions (with trailing parentheses omitted here), except for `pi` and `e`.

For more details, see the Python Library Reference, or import `math` and run `help(math.`*`name`*`)` for arguments and notes for any name in this table, and `dir(math)` to see module content. Also see the `cmath` standard library module for complex number tools, and the *NumPy* third-party system (and others) on the Web for advanced numeric work.

*Table 25. math module exports in Python 3.3*

| | | | | |
|---|---|---|---|---|
| acos | acosh | asin | asinh | atan |
| atan2 | atanh | ceil | copysign | cos |
| cosh | degrees | e | **erf** | **erfc** |
| exp | **expm1** | fabs | factorial | floor |
| fmod | frexp | fsum | **gamma** | hypot |
| **isfinite** | isinf | isnan | ldexp | **lgamma** |
| log | log10 | log1p | **log2** | modf |
| pi | pow | radians | sin | sinh |
| sqrt | tan | tanh | trunc | |

## The time Module

Utilities related to *time and date*: time access, formatting, and pauses. Following is a partial list of `time` module exports. See also "The datetime Module", "The timeit Module", and the Python Library Reference for more details:

`time.clock()`
: Returns the CPU time or real time since the start of the process or since the first call to `clock()`. Precision and semantics are platform-dependent (see Python manuals). Returns seconds expressed as a floating-point number. Useful for benchmarking and timing alternative code sections.

`time.time()`
: Returns a floating-point number representing UTC time in seconds since the epoch. On Unix, epoch is 1970. May have better precision than `clock()` on some platforms (see Python manuals).

`time.ctime(`*`secs`*`)`
: Converts a time expressed in seconds since the epoch to a string representing local time (e.g., `ctime(time())`). The argument is optional and defaults to the current time if omitted.

`time.sleep(`*`secs`*`)`
: Suspends the process's (calling thread's) execution for *`secs`* seconds. *`secs`* can be a float to represent fractions of seconds.

The next two calls are available in *Python 3.3* and later only. They are designed to provide timing data portably (but may not be directly comparable with calls in earlier Python versions). For both, the reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid:

`time.perf_counter()`
: Returns the value in fractional seconds of a performance counter, defined as a clock with the highest available resolution to measure a short duration. It includes time elapsed during sleep states and is systemwide. Can be thought of as wall time, and if present, is used by default in the `timeit` module.

`time.process_time()`
: Returns the value in fractional seconds of the sum of the system and user CPU time of the current process. It does not include time elapsed during sleep, and is process-wide by definition.

## The timeit Module

Tools for portably *measuring execution time* of a code string or function call. See Python's manuals for complete details.

**Command-line interface:**

```
py[thon] -m timeit [-n number] [-r repeat]
         [-s setup]* [-t] [-c] [-p] [-h] [statement]*
```

Where *`number`* is times to run statements (default is a computed power of 10); *`repeat`* is runs to make (default 3); *`setup`* (zero or more, each with `-s`) is code to run before timed statements; *`statement`* (zero or more) is the code to be timed; `-h` prints help; and `-t`, `-c`, and `-p` specify timers to use—`time.time()`, `time.clock()`, or as of Python 3.3 `time.process_time()` (else

`time.perf_counter()` is the default in 3.3 and later). Displayed results give the best time among the *`repeat`* runs made, which helps neutralize transient system load fluctuations.

**Library API interface:**

```
timeit.Timer(stmt='pass', setup='pass', timer=dflt)
```

Used by the following convenience functions. Both `stmt` and `setup` are either a code string (use `;` or `\n` to separate multiple statements, and spaces or `\t` for indentation), or a no-argument callable. The `timer` function's default, *`dflt`*, is platform and version-dependent.

```
timeit.repeat(stmt='pass', setup='pass',
              timer=dflt, repeat=3, number=1000000)
```

Creates a `Timer` instance with the given `stmt` and `setup` code and `timer` function, and runs its `repeat` method with `repeat` count and `number` executions. Returns list of timing results: take its `min()` for best of `repeat` times.

```
timeit.timeit(stmt='pass', setup='pass',
              timer=dflt, number=1000000)
```

Creates a `Timer` instance with the given `stmt` and `setup` code and `timer` function and run its `timeit` method with `number` executions. Runs `setup` once; returns time to run `stmt` `number` times.

## The datetime Module

Tools for *date processing*: subtracting dates, adding days to dates, and so on. See also "The time Module", and the Python Library Reference for more tools and details.

```
>>> from datetime import date, timedelta
>>> date(2013, 11, 15) - date(2013, 10, 29) # Between
datetime.timedelta(17)

>>> date(2013, 11, 15) + timedelta(60)      # Future
datetime.date(2014, 1, 14)
>>> date(2013, 11, 15) - timedelta(410)     # Past
datetime.date(2012, 10, 1)
```

## The random Module

Assorted *randomization* calls: random numbers, shuffles, and selections. See Python manuals for full details.

```
>>> import random
>>> random.random()          # Random float in [0, 1)
0.7082048489415967
>>> random.randint(1, 10)    # Random int in [x, y]
8
>>> L = [1, 2, 3, 4]
>>> random.shuffle(L)        # Shuffle L in place
>>> L
[2, 1, 4, 3]
>>> random.choice(L)         # Choose random item
4
```

## The json Module

Utilities for translating Python dictionary and list structures to and from JSON text—a portable *data representation format*, used by systems such as MongoDB (per BSON), and Android's SL4A (in JSON-RPC). See also Python's native object serialization in "The pickle Module"; XML support in "Internet Modules and Tools"; and other database concepts in "Python SQL Database API".

```
>>> R = {'job': ['dev', 1.5], 'emp': {'who': 'Bob'}}

>>> import json
>>> json.dump(R, open('savejson.txt', 'w'))
>>> open('savejson.txt').read()
'{"emp": {"who": "Bob"}, "job": ["dev", 1.5]}'
>>> json.load(open('savejson.txt'))
{'emp': {'who': 'Bob'}, 'job': ['dev', 1.5]}

>>> R = dict(title='PyRef5E', pub='orm', year=2014)
>>> J = json.dumps(R, indent=4)
>>> P = json.loads(J)
>>> P
{'year': 2014, 'title': 'PyRef5E', 'pub': 'orm'}
>>> print(J)
```

```
{
    "year": 2014,
    "title": "PyRef5E",
    "pub": "orm"
}
```

## The subprocess Module

Tools for running *command lines*, tapping into any of their three streams, fetching exit codes, and specifying shell execution, which are alternatives to some `os` module tools such as `os.popen()` and `os.spawnv()`; see "The os System Module" and Python manuals for further details. Hint: do not use these tools to launch untrustworthy shell command strings, as they may run any command allowed for the Python process. In the following, script *m.py* prints its `sys.argv` command line:

```
>>> from subprocess import call, Popen, PIPE
>>> call('python m.py -x', shell=True)
['m.py', '-x']
0
>>> pipe = Popen('python m.py -x', stdout=PIPE)
>>> pipe.communicate()
(b"['m.py', '-x']\r\n", None)
>>> pipe.returncode
0
>>> pipe = Popen('python m.py -x', stdout=PIPE)
>>> pipe.stdout.read()
b"['m.py', '-x']\r\n"
>>> pipe.wait()
0
```

## The enum Module

Available as of Python 3.4, this module provides standard support for *enumerations*—sets of symbolic names (a.k.a. *members*) bound to unique, constant values. Not to be confused with the `enumerate()` call, used to sequentially number iterator results (see "Built-in Functions"):

```
>>> from enum import Enum
>>> class PyBooks(Enum):
```

```
        Learning5E = 2013
        Programming4E = 2011
        PocketRef5E = 2014

>>> print(PyBooks.PocketRef5E)
PyBooks.PocketRef5E
>>> PyBooks.PocketRef5E.name,
    PyBooks.PocketRef5E.value
('PocketRef5E', 2014)

>>> type(PyBooks.PocketRef5E)
<enum 'PyBooks'>
>>> isinstance(PyBooks.PocketRef5E, PyBooks)
True
>>> for book in PyBooks: print(book)
...
PyBooks.Learning5E
PyBooks.Programming4E
PyBooks.PocketRef5E

>>> bks = Enum('Books', 'LP5E PP4E PR5E')
>>> list(bks)
[<Books.LP5E: 1>, <Books.PP4E: 2>, <Books.PR5E: 3>]
```

## The struct Module

The `struct` module provides an interface for parsing and constructing *packed binary data* as strings, per formats designed to mirror C language `struct` layouts. Often used in conjunction with the `'rb'` and `'wb'` binary files modes of `open()`, or other binary data source. See the Python Library Reference for *`format`* datatype and endian codes.

*`string`*`= struct.pack(`*`format, v1, v2, ...`*`)`

Returns a *`string`* (a `bytes` in 3.X and a `str` in 2.X) containing the values *`v1`*, *`v2`*, etc., packed according to the given *`format`* string. The arguments must match the values required by the *`format`* string's type codes exactly. The *`format`* string can specify the endian format of the result in its first character, as well as repeat counts for individual type codes.

*tuple* = struct.unpack(*format*, *string*)
: Unpacks the *string* (a bytes in 3.X and a str in 2.X) into a tuple of Python object values, according to the given *format* string.

struct.calcsize(*format*)
: Returns size of the struct (and hence of the byte string) corresponding to the given *format*.

Following is an example showing how to pack and unpack data using struct in Python 3.X (Python 2.X uses normal str strings instead of bytes; Python 3.X requires bytes for s values as of 3.2, not str; and '4si' in the following means the same as C's char[4]+int):

```
>>> import struct
>>> data = struct.pack('4si', b'spam', 123)
>>> data
b'spam{\x00\x00\x00'
>>> x, y = struct.unpack('4si', data)
>>> x, y
(b'spam', 123)

>>> open('data', 'wb').write(
                        struct.pack('>if', 1, 2.0))
8
>>> open('data', 'rb').read()
b'\x00\x00\x00\x01@\x00\x00\x00'
>>> struct.unpack('>if', open('data', 'rb').read())
(1, 2.0)
```

## Threading Modules

Threads are lightweight processes that share global memory (i.e., lexical scopes and interpreter internals) and *run functions in parallel* (concurrently) within the same process. Python thread modules work portably across platforms. They are suited for running nonblocking tasks in IO-bound and user-interface contexts.

See also setcheckinterval() and setswitchinterval() in "The sys Module", as well as the multiprocessing standard library

module which implements a threading-like API for portably spawned processes:

`_thread` (named `thread` in Python 2.X)
: Basic and low-level thread module, with tools to start, stop, and synchronize functions run in parallel. To spawn a thread: `_thread.start_new_thread(`*`function, args`* `[,` *`kargs`*`])` runs *`function`* in a new thread, with positional arguments from tuple *`args`*, and keyword arguments from dictionary *`kargs`*. `start_new_thread` is a synonym for `start_new` (which is documented as obsolete in 3.X). To synchronize threads, use thread locks: *`lock`*`=thread.allocate_lock(); `*`lock`*`.acquire(); `*`update-objects`*`; `*`lock`*`.release()`.

`threading`
: Module `threading` builds upon `thread` to provide customizable threading-oriented tools: `Thread`, `Condition`, `Semaphore`, `Lock`, `Timer`, daemonic threads, thread joins (waits), etc. Subclass `Thread` to overload `run` action method. This is functionally richer than `_thread`, but also requires more code in simpler use cases.

`queue` (named `Queue` in Python 2.X)
: A multiproducer, multiconsumer FIFO queue of Python objects, especially useful for threaded applications. Automatically locks its `get()` and `put()` operations to synchronize access to data on the queue. See the Python Library Reference.

# Python SQL Database API

Python's portable SQL-based *relational database* API provides script portability between different vendor-specific SQL database packages. For each vendor, install the vendor-specific extension module, but write your scripts according to the portable database API. Your standard SQL database scripts will largely continue working unchanged after migrating to a different underlying vendor package.

Note that most database extension modules are not part of the Python standard library; they are *third-party* components that must be fetched and installed separately. Exception: the SQLite embedded in-process relational database package is included with Python as *standard library* module `sqlite3`, intended for program data storage and prototyping.

See also "Object Persistence Modules" for simpler storage alternatives. There are additional popular database tools in the third-party domain, including *MongoDB*'s JSON document storage; object-oriented databases such as *ZODB* and others; object-relational mappers including *SQLAlchemy* and *SQLObject*; and cloud-oriented APIs such as *App Engine*'s data store.

## API Usage Example

The following uses the SQLite standard library module, and omits some return values for space. Usage for enterprise-level database such as MySQL, PostgreSQL, and Oracle are similar, but require different connection parameters and installation of extension modules, and may support vendor-specific (and non-portable) SQL extensions:

```
>>> from sqlite3 import connect
>>> conn = connect(r'C:\code\temp.db')
>>> curs = conn.cursor()

>>> curs.execute('create table emp (who, job, pay)')
>>> prefix = 'insert into emp values '
>>> curs.execute(prefix + "('Bob', 'dev', 100)")
>>> curs.execute(prefix + "('Sue', 'dev', 120)")

>>> curs.execute("select * from emp where pay > 100")
>>> for (who, job, pay) in curs.fetchall():
...     print(who, job, pay)
...
Sue dev 120

>>> result = curs.execute("select who, pay from emp")
>>> result.fetchall()
[('Bob', 100), ('Sue', 120)]
```

```
>>> query = "select * from emp where job = ?"
>>> curs.execute(query, ('dev',)).fetchall()
[('Bob', 'dev', 100), ('Sue', 'dev', 120)]
```

## Module Interface

This and the following sections provide a *partial* list of exports; see the full API specification at *http://www.python.org* for details omitted here. Tools at the top-level of the interface module (*dbmod*):

*dbmod*`.connect(`*parameters...*`)`
: Constructor for a connection object (*conn*) that represents a connection to the database. Parameters are vendor-specific.

*dbmod*`.paramstyle`
: String giving type of parameter marker formatting (e.g., `qmark` = `?` style).

*dbmod*`.Warning`
: Exception raised for important warnings, such as data truncations.

*dbmod*`.Error`
: Exception that is the base class of all other error exceptions.

## Connection Objects

Connection objects (*conn*) respond to the following methods:

*conn*`.close()`
: Closes the connection now (rather than when `__del__` is called).

*conn*`.commit()`
: Commits any pending transactions to the database.

*conn*.rollback()
: Rolls database back to the start of any pending transaction; closing a connection without committing the changes first will cause an implicit rollback.

*conn*.cursor()
: Returns a new cursor object (*curs*) for submitting SQL strings through the connection.

## Cursor Objects

Cursor objects (*curs*) represent database cursors, used to manage the context of a fetch operation:

*curs*.description
: Sequence of seven-item sequences; each contains information describing one result column: (*name*, *type_code*, *display_size*, *internal_size*, *precision*, *scale*, *null_ok*).

*curs*.rowcount
: Specifies the number of rows that the last `execute*` variant produced (for DQL statements like `select`) or affected (for DML statements like `update` or `insert`).

*curs*.callproc(*procname* [, *parameters*])
: Calls a stored database procedure with the given name. The sequence of parameters must contain one entry for each argument that the procedure expects; result is returned as a modified copy of the inputs.

*curs*.close()
: Closes the cursor now (rather than when `__del__` is called).

*curs*.execute(*operation* [, *parameters*])
: Prepares and executes a database operation (query or command); parameters can be specified as a list of tuples to insert multiple rows in a single operation (but `executemany()` is preferred).

*curs*.executemany(*operation*, *seq_of_parameters*)
: Prepares a database operation (query or command) and executes it against all parameter sequences or mappings in sequence *seq_of_parameters*. Similar to multiple execute() calls.

*curs*.fetchone()
: Fetches the next row of a query result set, returning a single sequence, or None when no more data is available. Useful for large data sets or slow delivery speed.

*curs*.fetchmany([size=*curs*.arraysize])
: Fetches the next set of rows of a query result, returning a sequence of sequences (e.g., a list of tuples). An empty sequence is returned when no more rows are available.

*curs*.fetchall()
: Fetches all (or all remaining) rows of a query result, returning them as a sequence of sequences (e.g., a list of tuples).

### Type Objects and Constructors

Date(*year*, *month*, *day*)
: Constructs an object holding a date value.

Time(*hour*, *minute*, *second*)
: Constructs an object holding a time value.

None
: SQL NULL values are represented by the Python None on input and output.

## More Hints and Idioms

This section briefly gives common Python coding patterns and usage hints, beyond those disclosed throughout this book. Consult the Python Library Reference and Python Language Reference (*http://www.python.org/doc/*) and the Web at large for further information on some topics mentioned here.

## Core Language Hints

- `S[:]` makes a top-level (shallow) copy of any sequence; `copy.deepcopy(X)` makes full copies; `list(L)` and `D.copy()` copy lists and dictionaries (also `L.copy()` for lists as of 3.3).
- `L[:0]=iterable` inserts multiple items in `iterable` at front of list `L`, in-place.
- `L[len(L):]=iterable`, `L.extend(iterable)`, and `L+=iterable` all insert multiple items in `iterable` at the end of a list `L`, in-place.
- `L.append(X)` and `X=L.pop()` can be used to implement in-place stack operations, where `X` is stacked items, and the end of the list is the top of the stack.
- Use `for key in D.keys()` to iterate through dictionaries, or simply `for key in D` in version 2.2 and later. In Python 3.X, these two forms are equivalent, since `keys()` returns an iterable view.
- Use `for key in sorted(D)` to iterate over dictionary keys in sorted fashion in version 2.4 and later; the form `K=D.keys(); K.sort(); for key in K:` also works in Python 2.X but not Python 3.X, since `keys()` results are view objects, not lists.
- `X=A or B or None` assigns `X` to the first true object among `A` and `B`, or else `None` if both are false (i.e., `0` or empty).
- `X,Y = Y,X` swaps the values of `X` and `Y` without requiring assignment of `X` to an explicit temporary.
- `red, green, blue = range(3)` assigns integer series as a simple name enumeration; class attributes and dictionaries may also suffice as enumerations. In Python 3.4 and later, see the more explicit and functionally rich support of enumerations in the `enum` standard library module.

- Use `try/finally` statements to ensure that arbitrary termination code is run; especially useful around locked operations (e.g., acquire a lock before the `try`, and release it in the `finally` block).
- Use `with/as` statements to guarantee that object-specific termination code is run for objects that support the context manager protocol only (e.g., file auto-close, tread lock auto-release).
- Wrap iterables in a `list()` call to view all their results interactively in Python 3.X, and to ensure that multiple traversals work properly; this includes `range()`, `map()`, `zip()`, `filter()`, `dict.keys()`, and more.

## Environment Hints

- Use `if __name__ == '__main__':` to add self-test code or a call to a main function at the bottom of module files; true only when a file is run, not when it is imported as a library component.
- To load file contents in a single expression, use *`data`*`=open(`*`filename`*`).read()`. Outside CPython, explicit close calls may be required to force immediate reclamation of system resources (e.g., within loops).
- To iterate through text files by lines, use `for` *`line`* `in` *`file`* in version 2.2 and later. (In older versions, use `for` *`line`* `in` *`file`*`.xreadlines()`.)
- To retrieve command-line arguments, use `sys.argv`.
- To access shell environment settings, use `os.environ`.
- The standard streams are: `sys.stdin`, `sys.stdout`, and `sys.stderror`.
- To return a list of files matching a given pattern, use: `glob.glob(`*`pattern`*`)`.

- To return a list of files and subdirectories on a path (e.g., "."), use: `os.listdir(path)`.
- To walk an entire tree of directories, use `os.walk()` in Python 3.X and 2.X. (`os.path.walk()` is also available in Python 2.X only.)
- To run shell commands within Python scripts, you can use `os.system(cmdline)`, `output=os.popen(cmdline, 'r').read()`. The latter form reads the spawned program's standard output, and may also be used to read line-by-line and interleave operations.
- Other streams of a spawned command are available via the `subprocess` module in both Python 3.X and 2.X, and the `os.popen2/3/4()` calls in Python 2.X only. The `os.fork()`/`os.exec*()` calls have similar effect on Unix-like platforms.
- To make a file an executable script on Unix-like platforms, add a line like `#!/usr/bin/env python` or `#!/usr/local/bin/python` at the top and give the file executable permissions with a `chmod` command.
- On Windows, files can be clicked and run directly due to registered filename associations. As of 3.3, the Windows launcher also recognizes `#!` Unix-style lines: see "Python Windows Launcher Usage".
- `print()` and `input()` (known as `print` and `raw_input()` in Python 2.X) use `sys.stdout` and `sys.stdin` streams: assign to file-like objects to redirect I/O internally, or use the `print(..., file=F)` form in Python 3.X (or the `print >> F, ...` form in Python 2.X).
- Set environment variable `PYTHONIOENCODING` to `utf8` (or other) if your scripts fail when printing non-ASCII Unicode text, such as file names and content.

## Usage Hints

- Use `from __future__ import` *`featurename`* to enable pending language changes that might break existing code, but enable version compatibility.
- Intuition about performance in Python programs is usually wrong: always measure before optimizing or migrating to C. Use the `profile`, `time`, and `timeit` modules (as well as `cProfile`).
- See modules `unittest` (a.k.a. *PyUnit*) and `doctest` for automated testing tools shipped with the Python standard library; `unittest` is a sophisticated class framework; `doctest` scans documentation strings for tests and outputs to rerun interactive sessions.
- The `dir([`*`object`*`])` function is useful for inspecting attribute namespaces; `print(`*`object`*`.__doc__)` gives raw docstring documentation.
- The `help([`*`object`*`])` function provides interactive help for modules, functions, types, type methods, and more; `help(str)` gives help on the `str` type; `help('`*`module`*`')` gives help on modules even if they have not yet been imported; and `help('`*`topic`*`')` gives help on keywords and other help topics (use `'topics'` for a list of help topics).
- See *PyDoc*'s `pydoc` library module and script shipped with Python for extraction and display of documentation strings associated with modules, functions, classes, and methods; `python -m pydoc -b` launches PyDoc's browser-based interface as of 3.2 (else use `-g` instead of `-b` for GUI client mode).
- See "Warnings Framework", as well as `-W` in "Python Command Options", for details about turning off future-deprecation warnings emitted by the interpreter.
- See *Distutils*, *eggs*, the next bullet's items, and others for Python program distribution options.

- See *PyInstaller*, *py2exe*, *cx_freeze*, *py2app*, and others for packaging Python programs as standalone executables (e.g., *.exe* files for Windows).
- See *NumPy*, *SciPy*, *Sage*, and related packages for extensions that turn Python into a numeric or scientific-programming tool with vector objects, mathematical libraries, etc. Also watch for the new basic `statistics` standard library module in Python 3.4.
- See *ZODB* and others for full-featured OODB support that allows Python native objects to be stored by key, and *SQLObject*, *SQLAlchemy*, and others for object relational mappers that allow classes to be used with relational tables. See *MongoDB* for a JSON-based "NoSQL" database option.
- See *Django*, *App Engine*, *Web2py*, *Zope*, *Pylons*, *TurboGears*, and others for Python Web development frameworks.
- See *SWIG* (among others) for a tool that can automatically generate glue code for using C and C++ libraries within Python scripts.
- See *IDLE* for a development GUI shipped with Python, with syntax-coloring text editors, object browsers, debugging, etc.; see also *PythonWin*, *Komodo*, *Eclipse*, *NetBeans*, and others for additional IDE options.
- See *Emacs* help for tips on editing/running code in the Emacs text editor. Most other editors support Python as well (e.g., auto-indenting, coloring), including *VIM* and *IDLE*; search for the Python editors' page at *http://www.python.org*.
- Porting to Python 3.X: use the `-3` command-line option in Python 2.X to issue incompatibility warnings, and see the *2to3* script, which automatically converts much 2.X code to run under 3.X Python. See also *six*, a system which provides a 2.X/3.X compatibility layer; *3to2*, which aspires to

convert 3.X code to run on 2.X interpreters; and *pies*, which also promotes line compatibility.

## Assorted Hints

- Relevant websites to refer to:

  *http://www.python.org*
  : The Python home page

  *http://oreilly.com*
  : The publisher's home page

  *http://www.python.org/pypi*
  : Additional third-party Python tools

  *http://www.rmi.net/~lutz*
  : The author's book support site

- Python philosophy: `import this`.
- You should say `spam` and `eggs` instead of `foo` and `bar` in Python examples.
- Always look on the bright side of life.

# Index


## Symbols

#! launcher file directives, 10
% operator, 28
- program specification, 6
-3 Python option, 7

## A

abs function, 134
all function, 134
any function, 134
apply function (Python 2.X), 156
arguments
  command line, 6
  functions, 76, 82
ArithmeticError class, 162
as clause, 89, 102
ascii function, 134
assert statement, 101
AssertionError class, 163
assignment statement, 72–76
AttributeError class, 163
attributes
  built-in, 172
  class attributes, 95, 109
  file, 62
  namespaces and, 105, 109
  number operations, 23
  pseudo-private, 110
  state retention and, 85
augmented assignments, 73
augmented binary methods, 127

## B

-b Python option, 4
-B Python option, 4
backslash escape sequences, 26
base classes, 95
base64 module, 223
BaseException class, 162
basestring function (Python 2.X), 156
__bases__ attribute, 173
bin function, 135
binary methods, 125–128
binascii module, 223
binhex module, 223
BlockingIOError class, 168


*We'd like to hear your suggestions for improving our indexes. Send email to index@oreilly.com.*

blocks, 67
bool function, 135
Boolean operations, 16
Boolean type, 66
break statement, 81
BrokenPipeError class, 168
buffer function (Python 2.X), 157
BufferError class, 162
buffering (open function), 146
buffering (streams), 5, 181
built-in attributes, 172
built-in exceptions, 161–172
  Python 2.X, 172
  Python 3.X, 171
  specific exceptions raised, 163–169
  superclasses, 162–163
  warning category exceptions, 169
  warnings framework, 170
built-in functions, 134–161
built-in operators
  operations by category, 16–20
  precedence and, 12–14
  sequence operation notes, 20–21
  usage notes, 14–16
built-in types, 21–67
  Boolean type, 66
  dictionaries, 53–57
  files, 58–63
  lists, 46–53
  numbers, 22–24
  operations by category, 16–20
  program-unit types, 66
  sets, 63–65
  strings, 24–42
  tuples, 57
  type conversions, 66
  Unicode strings, 42–46
bytearray function, 135
bytearray string type
  about, 25
  bytearray methods, 37
  string literals, 26
  Unicode and, 45
bytes function, 135
bytes string type
  about, 25
  bytes, 37
  string literals, 26
  Unicode and, 45
BytesIO, 59, 147
BytesWarning class, 170

## C

-c command specification, 6
callable function, 136
__cause__ attribute, 100
cgi module, 222
chained exceptions, 100
ChildProcessError class, 168
chr function, 136
class privates, 110
class statement, 95–97
  class decorators, 96
  metaclasses, 96
  OOP and, 109
classes
  class attributes, 95, 109
  class exceptions, 100
  class methods, 17–20, 109
  class statement, 95–97
  classic classes, 112
  new-style classes, 111–117
  OOP and, 109, 111
classmethod function, 95, 136
__class__ attribute, 172
closefd (open function), 147
closures, 107
cmp function (Python 2.X), 157
coerce function (Python 2.X), 157
command-line options
  format for, 3
  option variables, 9
  program specification, 5

Python 2.X, 7
Python 3.X, 4–5
script launcher, 11
comments, 68
comparisons, 16
compile function, 136
complex function, 137
composition, 216
compound statements, 71
comprehensions
dictionary, 53
generator, 52
list, 49, 53
set, 53
unqualified names and, 106
concatenated string constants, 26
ConnectionAbortedError class, 168
ConnectionError class, 168
ConnectionRefusedError class, 168
ConnectionResetError class, 168
constructors, 118, 236
context manager protocol, 103
context managers
files, 62
overloading methods for, 130
Python 2.7, 103
Python 3.X, 103
continue statement, 81
control flow, 67
conventions, 2
core widget classes (tkinter), 217


## D


-d Python option, 4
data descriptors, 130
datetime module, 227
dbm module, 211–213
decimal type, 23
decorators, 85, 96
def statement, 82–86
argument formats, 82
defaults and attributes, 84
function and method decorators, 85
lambda expressions, 84
Python 3.X, 83
del statement, 82
delattr function, 137
DeprecationWarning class, 169
descriptors
data, 130
file descriptor tools, 190–192
new-style inheritance, 114
overloading methods for, 129
destructors, 118
DFLR, 112
dict function, 137
dictionaries, 53–57
dictionary comprehensions, 53
literals and creation, 54
operations, 55–57
Python 2.X, 53
Python 3.X, 53
dictionary comprehensions, 53
__dict__ attribute, 172
dir function, 137
divmod function, 137
documentation strings, 68
dynamic typing, 12


## E


-E Python option, 4
else clause, 80–81, 98
email package, 223
encoding
non-ASCII character, 43
open function, 146
__enter__ method, 103
enum module, 229
enumerate function, 137
environment tools, 189
environment variables
command-line options and, 9

operational variables, 8
Windows script launcher, 11
EnvironmentError class, 171
EOFError class, 164
errors (open function), 146
escape codes, string constant, 27
eval function, 138
except clause, 97
Exception class, 162, 172
exception names, 71
exceptions, 106
(see also built-in exceptions)
chained exceptions, 100
class exceptions, 100
raise statement and, 99–101
try statement and, 97
unqualified names and, 106
exec function, 138
exec statement (Python 2.X), 104
execfile function (Python 2.X), 157
__exit__ method, 104
expression operators
atomic terms, 12
dynamic typing, 12
precedence, 12–14
usage notes, 14–16
expression statement, 76–77

## F

factory functions, 86
file descriptor tools, 190–192
file function, 58
file function (Python 2.X), 157
file pathname tools, 193–197
FileExistsError class, 168
FileNotFoundError class, 168
files, 58–63
any files (operations), 61
attributes, 62
file context managers, 62
file function, 58
input files, 59
open function, 58
output files, 60
usage notes, 63
filter function, 138
finally clause, 97
float function, 139
FloatingPointError class, 164
for loops, nested in list comprehensions, 49
for statement, 80–81
format function, 139
Formatter class, 183
fraction type, 23
from clause, 88, 100
from statement, 93–94
frozenset function, 64, 139
ftplib module, 222
function headers, 75
functional programming, 108
functions
built-in functions, 134–161
call syntax, 76
creating, 82
factory functions, 86
functional programming, 108
generator functions, 87–88
method functions, 95
FutureWarning class, 170

## G

garbage collection, 12, 62, 82
generator expressions, 51
generator functions, 87–88
GeneratorExit class, 164
getattr function, 139
glob.glob function, 185, 193, 238
global statement, 88
globals function, 139

## H

-h Python option, 4
hasattr function, 139
hash function, 140

help function, 140
hex function, 140
hints and idioms, 236–242
  core language hints, 237
  environment hints, 238–239
  usage hints, 240–242
  websites, 242
html package, 223
http.client module, 223
http.server module, 223

## I

-i Python option, 4
id function, 140
if statement, 80
imaplib module, 222
immutable objects
  dictionary keys, 54
  numbers, 22
  sets, 63
  strings, 24
  tuples, 57
import algorithm, 92
__import__ function, 140
import statement, 89–93
ImportError class, 164
ImportWarning class, 170
indentation, 68–69
IndentationError class, 164
IndexError class, 164
indexing, 20
inheritance
  classic classes, 112
  inheritance rules, 109, 112–117
  new-style classes, 112–117
  qualified names and, 105
inheritance algorithm, 114–116
__init__ method, 118
__init__.py file, 91
input files, 59
input function, 140
input function (Python 2.X), 158
instance objects, 95
instances, 109
int function, 141
int number type, 22
intern function (Python 2.X), 158
Internet modules, 221–224
InterruptedError class, 168
io module, 58, 147
IOError class, 171
is* string methods, 41
IsADirectoryError class, 169
isinstance function, 141
issubclass function, 141
items method, 53
iter function, 141
iteration protocol, 50, 87
iterators, 81
__iter__ method, 51, 88

## J

joining strings, 39
json module, 228

## K

KeyboardInterrupt class, 164
KeyError class, 164
keys method, 53

## L

lambda expressions, 84
len function, 142
lexical scopes, 105–107
list function, 142
lists, 46–53
  generator expressions, 51
  iteration protocol, 50
  list comprehension expressions, 49, 53
  literals and creation, 46
  operations, 47
locals function, 142
long function (Python 2.X), 158
long type, 22

LookupError class, 163
loop variables, 108

## M

-m module specification, 6
map function, 49, 142
mapping operations, 19, 123–125
mapping type category, 17
match objects, 205
math module, 224
max function, 143
MemoryError class, 165
memoryview function, 143, 156
metaclasses
  class statement and, 96
  new-style inheritance, 114
method functions, 95
methods
  binary methods, 125–128
  call syntax, 76
  class methods, 17–20, 109
  number operations, 23
  operator overloading methods, 95, 117–134
  self arguments, 95
  string, 34–41
min function, 143
module privates, 110
module search path, 90, 92
modules
  Internet, 221–224
  object persistence, 210–215
  standard library, 173, 210–215, 221–232
  threading, 231
MRO, 112–117
__mro__ attribute, 112, 173
mutable objects
  dictionaries, 53
  lists, 46
  sets, 63
mutable sequence operations, 18, 47
mutable type category, 17

## N

name rules, 69–71
NameError class, 165
namespace packages
  about, 91
  from statement and, 93
  import algorithm and, 92
  Python 2.X, 104
  Python 3.3, 91
namespaces, 105–108
  attributes and, 105, 109
  lexical scopes, 105–107
  object namespaces, 105
  qualified names, 105
  statically nested scopes, 107
  unqualified names, 105–107
__name__ attribute, 173
newline (open function), 146
next function, 87, 143
__next__ method, 51, 87
nntplib module, 223
non-ASCII character encoding, 43
None placeholder object, 65, 84, 86, 236
nonlocal statement, 89
NotADirectoryError class, 169
NotImplementedError class, 165
number operations, 125–129
number types
  decimal and fraction, 23
  immutable, 22
  literals and creation, 22
  operations, 23
  overloading methods for, 125–129
  third-party types, 24
numeric operations, 19

## O

-O Python option, 4
object class, 111

object function, 144
object persistence modules, 210–215
object serialization, 213–215
oct function, 144
-OO Python option, 4
OOP (object-oriented programming), 108–117
  attributes, 109–110
  classes, 109, 111
  inheritance, 109, 112–117
  instances, 109
open function, 58, 144–147, 160
opener (open function), 147
operational variables (environment), 8
operator overloading methods, 117–134
  for all types, 118–123
  for collections, 123–125
  for context managers, 130
  for descriptors, 129
  for numbers, 125–129
  Python 2.X methods, 131–134
  Python 3.X methods, 131
  specially named, 95
ord function, 148
os module, 184–202
  administrative tools, 185
  environment tools, 189
  file descriptor tools, 190–192
  file pathname tools, 193–197
  os.path module, 200–202
  portability constants, 186
  process control, 197–199
  shell commands, 187
os.path module, 200–202
OSError class, 163, 167, 171
output files, 60
OverflowError class, 165

## P

package imports, 91
pattern-matching module (see re module)
PendingDeprecationWarning class, 169
PermissionError class, 169
pickle module, 213–215
poplib module, 222
pow function, 148
precedence of expression operators, 12–14
print function, 148, 156
print statement (Python 2.X), 77–79
process control, 197–199
ProcessLookupError class, 169
program specification, 5
program-unit types, 66
programs, starting, 6
property function, 148
pseudo-private attributes, 110
PyDoc, 69, 240
Python 2.6
  class decorators, 96
  command options, 7
  number operations, 23
  operator usage notes, 15
  string types, 26, 45
Python 2.7
  class decorators, 96
  command options, 7
  context managers, 103
  dictionaries, 53
  operator usage notes, 15
  sets, 63
  string types, 26, 45
Python 2.X
  built-in attributes, 172
  built-in exceptions, 172
  built-in functions, 155–161
  command-line format, 7
  dictionaries, 53
  files, 63, 160
  generator expressions, 51

iteration protocol, 51
lists, 49
namespace packages, 104
numbers, 22
operator overloading methods for, 131–134
operator usage notes, 14–15
pickle module, 215
print statement, 79
raise statement forms, 101
sets, 63
statement support, 104
string methods, 38
string types, 25–26
try statement, 99
Unicode strings, 43, 46
Python 3.3
exceptions, 100
generator functions, 88
namespace packages, 91
Windows script launcher, 10
Python 3.4
enum module, 229
file descriptors, 191
operator usage notes, 16
pickle protocol, 216
star generalization, 75
Python 3.X
built-in exceptions, 171
chained exceptions, 100
class decorators, 96
context managers, 103
def statement, 83
dictionaries, 53
files, 63
number operations, 23
operator overloading methods for, 131
operator usage notes, 14
pickle module, 214
Python command options, 4
sets, 63
star generalization, 75
string types, 24
Unicode strings, 42–45
Windows script launcher, 10
Python programming language, 1
Python versions, 1
PYTHONCASEOK environment variable, 8
PYTHONDEBUG environment variable, 9
PYTHONDONTWRITEBYTECODE environment variable, 9
PYTHONFAULTHANDLER environment variable, 9
PYTHONHASHSEED environment variable, 9
PYTHONHOME environment variable, 8
PYTHONINSPECT environment variable, 9
PYTHONIOENCODING environment variable, 8
PYTHONNOUSERSITE environment variable, 9
PYTHONOPTIMIZE environment variable, 9
PYTHONPATH environment variable, 8
PYTHONSTARTUP environment variable, 8
PYTHONUNBUFFERED environment variable, 9
PYTHONVERBOSE environment variable, 9
PYTHONWARNINGS environment variable, 9

## Q

-q Python option, 4
-Q Python option, 7
qualified names (see namespaces)
quopri module, 223
quotes, 25

## R


-R Python option, 7
raise statement, 99–101
random module, 228
range function, 149
raw strings, 26
raw_input function (Python 2.X), 158
re module, 202–209
  match objects, 205
  module functions, 202–204
  pattern syntax, 207–209
  regular expression objects, 205
reduce function (Python 2.X), 158
ReferenceError class, 165
regular expression objects, 205
relative imports, 94
reload function (Python 2.X), 159
repr function, 149
ResourceWarning class, 170
return statement, 86–87
reversed function, 149
round function, 149
RuntimeError class, 165
RuntimeWarning class, 169


## S


-s Python option, 5
-S Python option, 5
scopes, 105–108
  lexical scopes, 105–107
  statically nested scopes, 107
script launcher (Windows), 10
scriptfile specification, 6
searching strings, 38
select module, 222
self argument, 95
sequence assignment, 74
sequence converters, 66
sequence operations
  lists, 47
  methods for, 17, 123–125
  notes, 20–21
  strings, 27
  tuples, 58
sequence type category, 17
serialization, object, 213–215
set comprehensions, 53, 53
set function, 150
set type, 24
setattr function, 150
sets, 63–65
  literals and creation, 63
  operations, 64
shell commands, 187
shelve module, 211–213
slice function, 150
slicing, 20
__slots__ attribute, 122
smtplib module, 222
socket module, 221
socketobj.makefile, 59, 147
socketserver module, 221
sorted function, 150
splitting strings, 39
SQL database API, 232–236
  API usage example, 233
  connection objects, 234
  cursor objects, 235
  module interface, 234
  type objects and constructors, 236
standard library modules, 173, 210–215, 221–232
StandardError class, 172
starting programs, 6
statements, 71–104
  assert statement, 101
  assignment statement, 72–76
  break statement, 81
  class statement, 95–97
  compound statements, 71
  continue statement, 81
  def statement, 82–86
  del statement, 82

exec statement (Python 2.X), 104
expression statement, 76–77
for statement, 80–81
from statement, 93–94
global statement, 88
if statement, 80
import statement, 89–93
name rules, 69–71
nonlocal statement, 89
print statement, 77–79
Python 2.X, 104
raise statement, 99–101
return statement, 86
suites, 71
syntax rules, 67
try statement, 97–99
while statement, 80
with statement, 102–104
yield statement, 87–88
statically nested scopes, 107
staticmethod function, 95, 151
StopIteration class, 165
str function, 151
str string type, 24, 37, 42
string module, 182–184
capwords function, 183
Formatter class, 183
maketrans function, 183
original, 41
Template class, 183
StringIO, 59, 147
strings, 24–42
backslash escape sequences, 26
bytearray methods, 37
bytearray string type, 25–26, 45
bytes, 37
bytes string type, 25–26, 45
content test methods, 41
formatting expressions, 28
formatting methods, 30–33, 39
formatting support, 28
literals and creation, 25–27
operations, 27
quotes, 25
searching, 38
splitting and joining, 39
str string type, 24, 37, 42
string constant escape codes, 27
string converters, 67
string methods, 34–41
string module, 41
template string substitution, 34
unicode string type, 25
Unicode strings, 42–46
struct module, 230
subprocess module, 229
suites (statements), 71
sum function, 152
super function, 113, 152
superclasses, 95, 109, 162–163
syntax rules, 67
SyntaxError class, 166
SyntaxWarning class, 169
sys module, 174–182
argv, 174
builtin_module_names, 174
byteorder, 174
copyright, 174
displayhook, 175
dont_write_bytecode, 175
excepthook, 175
exc_info, 175
executable, 175
exec_prefix, 175
exit, 176
flags, 176
float_info, 176
getcheckinterval, 176
getdefaultencoding, 176
getfilesystemencoding, 176
_getframe, 176

getrecursionlimit, 177
getrefcount, 176
getsizeof, 177
getswitchinterval, 177
getwindowsversion, 177
hexversion, 177
implementation, 177
intern, 177
int_info, 177
last_traceback, 178
last_type, 178
last_value, 178
maxsize, 178
maxunicode, 178
modules, 178
path, 178
platform, 179
prefix, 179
ps1, 179
ps2, 179
setcheckinterval, 179
setdefaultencoding, 180
setprofile, 180
setrecursionlimit, 180
setswitchinterval, 180
settrace, 181
stderr, 181
__stderr__, 181
stdin, 181
__stdin__, 181
stdout, 181
__stdout__, 181
thread_info, 182
tracebacklimit, 182
version, 182
version_info, 182
winver, 182
SystemError class, 166
SystemExit class, 166

## T

-t Python option, 7
TabError class, 167
telnetlib module, 223
Template class, 183
template string substitution, 34
third-party numeric types, 24
threading modules, 231
throw method, 88
time module, 225
timeit module, 226
TimeoutError class, 169
tkinter module, 216–220
additional classes and tools, 219
common dialog calls, 219
core widget classes, 217
example, 216
Tcl/Tk-to-Python/tkinter mappings, 220
try statement, 97–99
tuple function, 154
tuples, 57
type conversions, built-in types, 66
type function, 66, 154
TypeError class, 167

## U

-u Python option, 5
UnboundLocalError class, 167
unichr function (Python 2.X), 159
unicode function (Python 2.X), 159
unicode string type, 25, 27
Unicode strings, 42–46
bytes and bytearray, 45
Python 2.X support, 26, 46
Python 3.X support, 43
UnicodeDecodeError class, 167
UnicodeEncodeError class, 167
UnicodeError class, 167
UnicodeTranslateError class, 167
UnicodeWarning class, 170
unqualified names (see lexical scopes)

urllib.parse module, 222
urllib.request module, 222
user-defined names, rules for, 69–71
UserWarning class, 169
uu module, 223

## V

-v Python option, 5
-V Python option, 5
ValueError class, 167
values method, 53
variables
  dynamic typing, 12
  environment, 7–9, 11
  loop, 108
  name rules, 69–71
  namespace and scope rules, 106
vars function, 155
VMSError class, 171

## W

-W Python option, 5
Warning class, 169
warnings.warn function, 170
weak references, 165
while statement, 80
whitespace, 69
widget classes (tkinter), 217
Windows script launcher, 10
WindowsError class, 171
with statement, 102–104, 130

## X

-x Python option, 5
-X Python option, 5
xdrlib module, 221
xml package, 223
xmlrpc package, 223
xrange function (Python 2.X), 160

## Y

yield statement, 87–88

## Z

ZeroDivisionError class, 167
zip function, 155